HAPPY VALLEY INTERIM MEASURES WORK PLAN ADDENDUM AMENDMENT
HAPPY VALLEY AND BUILDING 359 AREAS OF CONCERN
SANTA SUSANA FIELD LABORATORY
VENTURA COUNTY, CALIFORNIA

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LIST OF ABBREVIATIONS

ACOE	Army Corps of Engineers
AL	Surface Water Action Level
AOC	Area of Concern
Boeing	The Boeing Company
bgs	below ground surface
CDFG	California Department of Fish and Game
Cal-EPA	California Environmental Protection Agency
COPC	chemical of potential concern
cy	cubic yards
DTSC	Department of Toxic Substances Control
FAL	field action level
gpm	gallons per minute
HVIM	Happy Valley Interim Measures
IM	Interim Measures
µg/L	micrograms per liter
µg/kg	micrograms per kilogram
mg/kg	milligrams per kilogram
mg/L	milligrams per liter
PCB	polychlorinated biphenyls
PQL	practical quantitation limit
RCRA	Resource Conservation and Recovery Act
RFI	RCRA Facility Investigation
RWQCB	Los Angeles Regional Water Quality Control Board
SSFL	Santa Susana Field Laboratory
USEPA	United States Environmental Protection Agency
USGS	Unites States Geological Survey

1.0 INTRODUCTION

This Amendment to the Happy Valley Interim Measures (HVIM) Work Plan Addendum presents additional information for the mitigative actions to control the release of perchlorate to surface water at the Happy Valley and Building 359 areas at the Santa Susana Field Laboratory (SSFL). It was prepared by MWH on behalf of The Boeing Company (Boeing) to address comments provided by the California Environmental Protection Agency (Cal-EPA) Department of Toxic Substances Control (DTSC) and Los Angeles Regional Water Quality Control Board (RWQCB) pertaining to the June 2003 HVIM Work Plan Addendum (MWH 2003b, DTSC 2003, RWQCB 2003). Copies of these agency comments, and the Boeing response to them, are provided in Appendix A of this Amendment.

The June 2003 HVIM Work Plan proposed the following actions to control the release of perchlorate to surface water at the Building 359 and Happy Valley areas:

- Four sources in soil at the Building 359 Area (Building 316, Building 376 [two areas] and Buildings 325/359) were proposed for treatment by composting. Composting has shown to degrade perchlorate in soils to the chloride ion. A source in soil at the southern Happy Valley site (Building 745) was also proposed for treatment by composting.
- A source in sediment above the upper reach of the Happy Valley drainage was proposed for excavation. The excavated sediment was to be transported to the Building 325/359 area and treated by composting, along with the existing in-place soils within the Building 325/359 area.
- The HVIM Work Plan also proposed additional characterization activities to identify if other sources of perchlorate occur at the Building 359 and Happy Valley area, and possible contingent measures that would be conducted if such sources were determined to exist. The proposed contingent measures included:
  - *In situ* bioremediation of soils beneath removed building foundations was to be performed if elevated concentrations of perchlorate were detected.
  - Either *in situ* composting or excavation/transport/treatment or disposal of drainage sediments may be necessary pending the results of characterizing the distribution of perchlorate in the Happy Valley drainage.
  - If sampling results indicate that bedrock contains perchlorate at concentrations that may leach to surface water at a significant rate, then the bedrock surface may be scraped and removed, sealed with an inert sealant, or covered/capped with an impermeable cover. Alternately, it may be most effective to temporarily re-route the

drainage around the exposed bedrock to prevent or minimize contact with storm water runoff.

- Finally, the sources that are being treated by composting can be covered with an impermeable cover during the rainy season to prevent contact with storm water runoff in these areas.

This HVIM Work Plan Addendum Amendment (HVIM Amendment) presents new, additional perchlorate sampling data collected at the Building 359 and Happy Valley sites that have been reported by the laboratory and reviewed between June 30 and August 12, 2003. The proposed scope of the HVIM has been refined based on these new data, agency comments, and site visits and discussion with DTSC and other regulatory permitting agencies, such as the RWQCB, California Department of Fish and Game (CDFG), and the Army Corps of Engineers (ACOE).

As requested by the agencies, this document provides additional information regarding the characterization and potential migration of perchlorate at the Building 359 and Happy Valley sites (Section 2), and additional detail regarding the interim measures to be performed to control perchlorate releases to surface water (Sections 3 and 4). The proposed interim measures presented in this Amendment augment and supercede those presented in the June 2003 HVIM Work Plan. As noted in Section 2, perchlorate sampling, analysis, and data review are continuing in support of the HVIM. It is possible that modifications to the specific scope of work presented in this Amendment may be required based on additional findings, and if so, these will be discussed with DTSC prior to implementation. The general conditions and criteria for additional actions are outlined in Sections 3 and 4.

The HVIM Amendment is meant to be a companion document to the June 2003 HVIM work plan. It provides only the new additional sampling data, and specific details regarding the implementation of the cleanup actions. Happy Valley and Building 359 facility background, location maps, and previous sampling information are presented in the June 2003 HVIM Work Plan. The objective and scope of the HVIM remains the same: to control perchlorate releases to surface water at the Happy Valley and Building 359 sites. The overall goal of the IM is to remove sources leaching perchlorate to surface water before the 2003/2004 winter rainy season.

Because of the prevalence of a state-listed sensitive species (Santa Susana Tarplant) in one small portion of a proposed HVIM treatment location, the implementation of the IM will be conducted in two phases. Santa Susana Tarplant is a California state-listed species and requires a special permit from the CDFG before work can proceed if it is determined that the project will cause adverse impacts to the Santa Susana Tarplant. This type of sensitive species CDFG permit can take up to 6 months for agency approval. Based on a July 17, 2003 site walk with CDFG, it was determined that any perchlorate cleanup action in the southwestern corner of the former Building 376 location will cause adverse impacts to the Santa Susana Tarplant present. Therefore, to avoid delaying the perchlorate cleanup in all other proposed areas, Phase I of the HVIM will address mitigation measures to be completed in all areas without Santa Susana Tarplant or in areas where Santa Susana Tarplant can be avoided. Phase II of the HVIM will be conducted in areas where impacts to Santa Susana Tarplant can not be avoided and a CDFG special permit will be obtained prior to conducting the interim measures in these areas.

2.0 ADDITIONAL HAPPY VALLEY AND BUILDING 359 PERCHLORATE SAMPLING INFORMATION

This section describes the sampling rationale used to characterize the Happy Valley and Building 359 areas, and provides preliminary results of new perchlorate samples available by August 12, 2003. As described in the HVIM Work Plan, the Happy Valley and Building 359 sites are identified as Areas of Concern (AOCs) at the SSFL, and are being investigated as part of the Resource Conservation and Recovery Act (RCRA) Facility Investigation (RFI).

Although this section focuses on the perchlorate characterization conducted at these sites, the overall RFI sampling rationale and approach is described as requested by DTSC. In addition, sampling results for other chemicals of potential concern (COPCs) at the Happy Valley and Building 359 sites are summarized. All sampling data for these two RFI sites will be included in the draft RFI report prepared when all site characterization is complete and following the implementation of this IM.

2.1 RFI SAMPLING RATIONALE

Soil vapor, soil matrix, and near-surface groundwater sampling at the Happy Valley and Building 359 sites for the RFI has been conducted following DTSC-approved work plan requirements and protocols (Ogden 1996, 2000a and 2000b). Soil sampling data collected prior to January 1999 are depicted on maps provided in a report entitled: *Preliminary RFI Soil Sampling Results, Santa Susana Field Laboratory. Ventura County, California* (Ogden 1999). Based on detailed site reviews by DTSC during 1999/2000, a significant amount of additional sampling has been conducted at these sites, particularly for perchlorate.

In general, the RFI soil sampling at these sites has targeted known or suspected chemical use areas (a biased sampling approach) to identify potential impacts to human health or the environment. Chemical use areas were identified based on published documents, facility maps and records, interviews with current employees, and review of historical photographs. Additional sampling decisions were based on a comparison of the results to DTSC-approved Field Action Levels (FALs). FALs are risk-based soil screening levels developed to aid in site

characterization decisions. Additional sampling was also performed if new chemical use information was obtained.

Summaries of the building operations, sampling rationale used and preliminary RFI results are provided for the Happy Valley and Building 359 Areas in Tables 1 and 2, respectively. As described above, detailed soil sampling rationale and results for each sample collected during the RFI will be provided in the RFI reports prepared for these sites. The following, however, is a summary of the COPC results (other than perchlorate) that exceed FALs in areas proposed for perchlorate cleanup during the HVIM.

Building 359/325 area. Mercury and arsenic are detected north and west of Building 359 at concentrations that exceed their FAL. Mercury was detected at concentrations up to 1.3 milligrams per kilogram (mg/kg), and arsenic to 94 mg/kg in surface and deep soils (to depths immediately above bedrock, approximately 15 to 25 feet below ground surface [bgs]). Total petroleum hydrocarbons, hexavalent chromium, and lead also were detected above FALs in surrounding soils.

Building 376 area (and northern surface water runoff area). Based on operations at Building 376 (perchlorate storage and handling), no other chemicals have been targeted in this area.

Building 316 and Former Tunnel Facility. Arsenic (up to 110 mg/kg) and mercury (up to 0.46 mg/kg) have been detected in surface and shallow soils (to depths above bedrock, approximately 3.5 feet bgs) in the Building 316 area. Elevated arsenic has been detected in shallow soils (less than 2 feet bgs) throughout the former tunnel facility. Although elevated dioxins and polychlorinated biphenyls (PCBs) were detected in residues within the confines of a former incinerator, these compounds were not detected at concentrations exceeding their FAL in the soil surrounding or below the incinerator. These burned materials from within the former incinerator were removed and disposed offsite following appropriate regulations prior to demolition of the building foundation.

Building 745. Other COPCs were not detected in this area above FALs.

Building 372 Area (upper drainage). Metals and RDX (an ordnance compound) were detected at concentrations above FALs in the former sumps at Building 372 and in the surrounding soils. Mercury, copper, and lead were previously detected above FALs in soils removed during the 1999 IM from the upper reach of the drainage, south of former Building 372 (Ogden 1999, UXB 2002). Subsequent soil sample results at this location indicate that the elevated metal concentrations were effectively removed from the area. However, to further ensure adequacy of this IM, additional characterization for metals in this area is ongoing and may influence final actions.

2.2 PERCHLORATE SAMPLING RATIONALE, METHODOLOGY, AND ANALYSIS PROTOCOLS

The following sections provide additional information regarding the rationale used to direct the perchlorate sampling at the Building 359 and Happy Valley sites, perchlorate leachate methodologies, and laboratory analysis methods used to ensure quality data.

2.2.1 Sampling Rationale

Sampling for perchlorate was added to the scope of the RFI at the Building 359 and Happy Valley sites in 1998, once perchlorate was identified as a COPC at other facilities within California. As described in the RFI work plans (Ogden 1996 and 2000a), the soil sampling approach during the RFI targets use areas (e.g., testing, mixing, storage locations) or collection units (e.g., sumps and ditches, termed 'contained units'). A biased sampling approach is used because site operational histories are generally well understood. Step-out sampling is performed for any detected perchlorate concentrations greater than the FAL. The perchlorate soil FAL has been set equivalent to the drinking water action level established by the California Department of Health Services (0.018 mg/L in 1998 and recently decreased to 0.004 mg/L in 2002). Potential perchlorate migration from a location is evaluated by collecting downslope soil or downstream sediment samples.

During 2001 and 2003, surface water samples were collected during the rainy season to aid in the identification of potential areas of soil or sediment perchlorate impacts. Surface water runoff

was collected either from behind small, temporary tarp/sand bag locations, or from natural pools and surface flow within the active drainage. DTSC was present during some of the Spring 2003 sampling events and selected many of the sampling locations.

2.2.2 Leachate Methodology

After the DTSC site review of the Happy Valley area, the soil sampling approach for perchlorate was revised under DTSC direction in October 2000 to include collection of soil leachate samples to screen for potential perchlorate impacts in soil. This approach was adopted because perchlorate compounds are highly soluble, and readily leach into water from soil. This method allowed testing of a larger amount of soil for perchlorate than the small aliquot removed from a typical sampling container by the laboratory for analysis. The majority of RFI soil leachate samples presented in the June 2003 HVIM work plan were obtained as follows:

- Multiple sampling sleeves were collected from a single vertical hand-auger borehole, multiple hand-auger boreholes within a small area (generally 5 feet by 5 feet), or a trench wall or floor. The number of sampling sleeves would vary depending on the area tested, but generally included 3 to 6 sleeves. In some instances, soils were collected directly from the hand auger or in locations where soil cover was thin, using a trowel.
- Sleeves were partially emptied into a clean 5-gallon bucket, and sufficient de-ionized water added to saturate the soil, plus approximately 1 to 2 inches of free water covering the soil. The soil-water mixture was then stirred, allowed to settle, and the water decanted into a plastic bottle obtained from the laboratory. The soil wetting process was repeated until the plastic sampling bottle was full (usually two to four times).
- The leachate water sample and the partially emptied sleeves were labeled, sealed, and sent to the analytical laboratory under chain-of-custody procedures. Leachate water samples were filtered and analyzed at the laboratory for perchlorate; associated soil samples were typically analyzed if perchlorate was detected in the leachate sample.

In some instances (specifically at the Happy Valley site near Building 372), other types of perchlorate screening samples were collected. These sampling methods were discussed and developed in conjunction with DTSC during the RFI field program. These sampling methods included performing artificial surface water runoff in focused areas near the Building 372 building foundation or drainage area to the south. In these instances, water samples were directly collected from low spots within the building foundation (sumps, ditches, etc.), or from collection points within the natural drainage.

The leachate samples obtained since the June 2003 IM Work Plan were collected using a slightly modified protocol based on recent information regarding similar perchlorate sampling methods at other perchlorate-impacted sites in California. The modified sampling procedure was implemented for the HVIM characterization since it allows for better quantification of perchlorate detected in the soils (i.e., a one-to-one water/soil ratio is used), and still targets both surficial and deeper sediments. The very surficial nature of the samples (at 0.5-inches) collected using the revised metholdology targets any salts, including perchlorate, that rise to the surface by capillary action as surface water evaporates. Side-by-side comparison samples were collected using both methods in known areas of impacts. The 'original' method samples are identified with a "S99" identifier.

The following describes the revised sampling and leachate preparation procedures used for the HVIM since June 30, 2003:

- Drainage sediments were sampled within the active channel as well as from the bank and overbank locations. Locations were selected at regular intervals down the drainage or in areas where visible salts were noted. Samples were collected as follows in the Happy Valley drainage or topographic lows within Building 359: S01 (active channel, 0.5-inch), S02 (active channel, 4-inch), S03 (bank, 4-inch), S04 (overbank, 0.5-inch), and S05, S06, S07, etc. (deeper active channel, 6-inch intervals to bedrock). Deeper samples were only collected where sediment thicknesses allowed. Leachates from these samples were prepared as described below.
- Soils beneath former building foundations were sampled between 0 and 6 inches from four locations within the outline of the building (some buildings were split in two or more areas based on size). These four samples were homogenized in the field and combined into one composite sample prior to leachate preparation (described below). This approach was used because of the disturbed nature of the soils after the foundation was removed.
- Leachates were prepared by mixing 250 grams of soil/sediment samples and 250 milliliters of deionized water in laboratory supplied, pre-cleaned containers. The soil-water mixtures were shaken for 2 minutes, allowed to settle for 15 minutes, and then shaken again and allowed to settle overnight. The water in the mixture was decanted as the 'leachate' sample and submitted to the laboratory for analysis under appropriate chain-of-custody procedures.

Review of the recent sample results (see Section 2.4) indicates that this has been an effective method in locating perchlorate in the Building 359 and Happy Valley soils and sediments. Comparison of original versus revised sampling results indicates that generally higher concentrations of perchlorate are detected in one of the four samples collected at a location using the revised approach compared to the original method.

2.2.3 Laboratory Analysis

Laboratory analysis for perchlorate is performed using United States Environmental Protection Agency (USEPA) Method 314.0. (Prior to establishment of USEPA Method 314.0, perchlorate analyses were performed following California Department of Health Services requirements for perchlorate analysis using a modified Method 300.) The typical soil matrix (or rock chip) sample reporting limit is 40 µg/kg, with a laboratory method detection limit of less than 20 µg/kg. Laboratories used for the RFI are required to report as estimated any perchlorate detected below the reporting limit but above the method detection limit. In contrast, the typical sample reporting limit for water samples is 4 µg/L, with a method detection limit of less than 1 µg/L. Because perchlorate is highly soluble and aqueous detection limits are an order of magnitude lower than those for soil, the leachate methodology was determined to be more sensitive at identifying locations with perchlorate in soil.

Naturally occurring matrix interference can cause some reporting limits for water or soil samples to be raised. Typical interference causing constituents include nitrate, sulfate, chloride, and several types of organic compounds. Recent research by the USEPA and commercial laboratories has identified additional steps that can be done prior to analysis to reduce matrix interference. The additional steps include utilizing a cartridge to remove the interfering constituent(s) without affecting perchlorate concentrations, and are acceptable within the USEPA Method 314.0. The laboratory must conduct and document that sufficient quality control sample procedures were performed to ensure that perchlorate was neither added nor removed by the additional procedures.

During the most recent sampling event (since June 2003), the analytical laboratories used for the HVIM sample analysis have been performing some of these additional steps for those samples

which exhibit raised reporting limits due to matrix interference. The laboratory would run the samples as submitted, and if interference caused an increased reporting limit, the sample would be passed through a cartridge to remove the interfering constituent, and the sample re-run. Appropriate quality control procedures were implemented by the laboratory to verify no change in potential perchlorate concentrations. Also, some samples would not require cartridge treatment, and could just be rerun with sufficient blank samples between the site samples to reduce instrument carryover. These procedures have been successfully used in the most recent analyses performed for the HVIM with almost all reporting limits equal to 4 µg/L for soil leachates or water samples.

In addition to these added laboratory measures to keep the detection limits as low as possible, the presence or absence of perchlorate at low concentrations was verified using laboratory spike samples (where the sample is analyzed after spiking it with a known amount of perchlorate).

2.3 RECENT PERCHLORATE SAMPLING RESULTS

This section describes recent perchlorate sampling results from the Building 359 and Happy Valley sites that have been reported by the laboratory and reviewed between June 30 and August 12, 2003. The recent results described in this section should be considered preliminary; although a qualified chemist has reviewed each sample result, the data validation reports have not been finalized. As described above, perchlorate characterization to refine the scope of the HVIM is continuing, primarily for sediments within the lower Happy Valley drainage, deeper bedrock horizons, soils at the former Building 359 building foundations, and in the Building 359 storm drain area.

Perchlorate results for sampling that conducted at the Happy Valley, Building 359, and elsewhere within the SSFL since January 2003 will be presented in an update to the comprehensive perchlorate report published in February 2003 (MWH 2003a). This updated perchlorate report is anticipated to be prepared by November 15, 2003.

Figure 1 presents recent soil leachate sampling results in the Happy Valley drainage. As explained in Section 2.2, drainage leachate samples were collected from closely spaced locations

and variable depths within the active channel, bank, and overbank. Since all these results are shown at one point within the map, the results at some locations are quite variable and represent the heterogeneity in perchlorate distribution within the channel. The inset box in Figure 1 provides a graphic representation of how sediment samples were labeled at a single sampling location within the drainage. Simulated rainfall sampling is ongoing in the lower reach of the drainage (below known impact areas), and samples are pending analysis. Simulated rainfall samples are artificially-induced surface water samples generated by dispersing fire-hydrant water over an area of the drainage.

These recent sediment leachate samples indicate an area of elevated perchlorate in the upper reach of the drainage, approximately 20 feet west of PZ-117 (HVLS42). In this area, perchlorate concentrations up to 320 micrograms per liter (µg/L) have been detected in leachate samples collected from bank sediments with visible salt incrustations. In general, the samples collected from the eastern channel of the drainage above sampling location HVLS37 contained perchlorate at concentrations greater than 4 µg/L. Although sampling continues, perchlorate has not been detected above 4 µg/L below the HVLS37 sampling location.

Figure 2 presents the recent bedrock chip sampling results in the upper reach of the Happy Valley drainage. This area was targeted for bedrock sampling because soil and debris from Building 372 activities were deposited above this portion of the drainage. The soil and debris were removed from above the now-exposed bedrock during the 1999 IM (UXB 2002). Surface bedrock chip samples (collected from the uppermost portion of exposed bedrock) indicate elevated concentrations of perchlorate exist in the bedrock surfaces beneath the surface water drainage. Concentrations of perchlorate detected in the bedrock underlying the surface water flow lines ranged from < 41 µg/kg (non-detect) to 4,100 µg/kg perchlorate. The highest concentration was detected in a stained portion of a large boulder at the uppermost bedrock exposure area. Characterization of the bedrock at deeper horizons is ongoing.

Figure 3 presents available soil leachate sampling results near building foundations or in topographic lows leading from the former buildings. Only limited new data have been reported by the laboratory for these samples, mostly in the downgradient area north of Building 376, in

the vicinity of the sealed storm drain. These samples contained up to 33 µg/L perchlorate in soil leachate samples. Review of additional sample data will continue pending further reporting by the laboratory.

2.4 CONCLUSIONS REGARDING THE OCCURRENCE AND TRANSPORT OF PERCHLORATE TO SURFACE WATER

The highest concentrations of perchlorate at the Building 359 and Happy Valley areas occur in the three areas that historically had the greatest amount of perchlorate use: the primary bulk storage area (Building 376); the mixing area (Building 359/325 area); and, the flare research and testing area (Building 372). Details regarding surface water fate and transport of perchlorate in these areas follow; details regarding the groundwater conditions in this area are described in the comprehensive perchlorate report (MWH 2003a).

Building 376 Area. Perchlorate concentrations in this area currently range up to 71 mg/kg in soil and 10 mg/L in leachate. Based on facility operations, these impacts are likely caused by incidental spillage at the bulk storage area. Wash down and natural surface water transport of perchlorate from this area has caused perchlorate soil impacts to the north, in the topographic depressions and in the channels leading to the storm drain along the Area I Road (now temporarily sealed). Investigation of soils along the northern extent of the storm drain is underway as part of this HVIM and will be further investigated during the Area I Landfill investigation to determine if perchlorate impacts extend to the north (MWH 2003c).

Building 359/325 Area. Perchlorate concentrations north of Building 359, where mixing occurred, range up to 2.9 mg/kg in shallow soil (1 foot bgs) adjacent to the former sump, indicating that the sump and/or inlet piping historically leaked. Perchlorate has been transported vertically downwards and is detectable up to 24.5 feet bgs, immediately above bedrock. As expected, perchlorate impacts are detected in nearby groundwater monitoring wells. Perchlorate concentrations near Building 325 range up to 4.66 mg/kg in shallow soils north of the building (1 foot bgs), indicating a surface release occurred in this area. Perchlorate concentrations near east of Building 325 range up to 0.190 mg/kg near a former drain. These impacts are likely related to mixing, handling, and wash-down of the perchlorate used in the building. Surface water runoff from these parts of the Building 359/325 area have resulted in elevated perchlorate

concentrations detected in the concrete-lined drainage ditch west of the site. Ultimately, these concentrations decrease with distance further down the ditch.

Building 372 Area. As described in the HVIM work plan and the comprehensive perchlorate report (MWH 2003a and 2003b), perchlorate-impacted soil (up to 0.16 mg/kg) and debris were removed from the topographic low south of Building 372 during the 1999 IM. This area appears to be the primary contributor to the perchlorate detected in the drainage sediments and surface water samples. Surface water transport of perchlorate in the Happy Valley drainage has caused impacts to near-surface groundwater in the upper and middle reaches of the drainage. Near-surface groundwater does not exist in the lower reach, near the property boundary. Where it exists near PZ-117 and PZ-74, perchlorate concentrations in near-surface groundwater are similar to those detected in surface water at those locations (decreasing from about 20 µg/L to about 8 µg/L) (MWH 2003a).

3.0 PROPOSED INTERIM MEASURES IN THE HAPPY VALLEY DRAINAGE AREA

Interim measures to be implemented in the Happy Valley drainage are designed to control the release of perchlorate in soil, sediment, and bedrock to surface water. These interim measures include a combination of excavation and *ex situ* biotreatment or disposal, and *in situ* biotreatment. Containment by sealing or tarping, or rerouting of storm water around bedrock areas that contain perchlorate, may be used if it is not feasible to remove significant bedrock impacts contributing to surface water runoff. The objective is to reduce the amount of perchlorate contacting storm water such that perchlorate concentrations in runoff from the Happy Valley drainage comply with the proposed water quality objective for perchlorate. Based on the current California Department of Health Services recommended action level, it is anticipated that this water quality objective will be 4 µg/L.

Additional measures that may be implemented to remove perchlorate from surface water to better assure compliance with the proposed water quality objective during the 2003/2004 wet weather season include deployment and/or construction of temporary storm water retention and/or diversion structures. Such facilities, if deployed, would only be operated until it was demonstrated through chemical analysis of surface water samples for perchlorate that the interim measures designed to prevent perchlorate from contacting and entering surface water were effective.

A decision tree that describes the rationale for all the interim measures proposed for implementation in the Happy Valley drainage is presented in Figure 4. Criteria for action for the various potential interim measure activities in the drainage are summarized in Table 3. Figure 5 shows the locations of potential interim measures to be implemented in the Happy Valley drainage as well as the approximate limits of the proposed excavation near and down-gradient from the source area.

The following sections provide details of the proposed interim measures for the Happy Valley drainage that were designed after considering information and data that have been collected since the HVIM Work Plan Addendum (MWH 2003b) was prepared. Specific comments pertaining to

the HVIM Work Plan Addendum that were provided by the RWQCB and DTSC (Appendix A) were also considered.

Soil leachate, simulated rainfall, and soil/bedrock concentrations triggering interim measure actions within the Happy Valley drainage are based on their expected contribution to surface water runoff. As described above, the goal for surface water runoff concentrations is 4 µg/L based on an anticipated water quality objective for perchlorate. Therefore, 4 µg/L has been defined for the HVIM as the surface water action level (AL). In the Happy Valley drainage area, soil leachate and simulated rainfall water sample concentrations 'triggering' action are conservatively considered to be 4 µg/L because of the uncertainty of the relationship between soil leachate or simulated rainfall samples to natural storm water runoff.

3.1 EXCAVATION, DRAINAGE CONTROL, AND BACKFILL ACTIVITIES

The following describes the IM activities to be performed in the Happy Valley drainage. They are presented in the general order that they will be conducted.

1. Excavate soil and sediments that contain greater than the AL in leachate or simulated rainfall samples in the upper reach of the Happy Valley drainage as shown on Figure 5. It is estimated that the excavation depth will average approximately 3 feet upstream of the rocky outcrop where the highest perchlorate concentrations have been detected, and 1.0 feet downstream of the rocky outcrop. In addition, loose sediments with perchlorate impacts on the bedrock outcrop will be removed. The total estimated excavation volume ranges from 1100 to 1500 cubic yards (cy). This estimated range is wide because sediment thickness and width of the channel varies along the drainage.

2. Selectively remove the upper 2 to 4 inches of bedrock surfaces that contain perchlorate at concentrations sufficiently high to potentially leach to storm water at concentrations above the AL. The approximate limits of the area where measures to mitigate the effects of perchlorate leaching from bedrock may be warranted are as shown on Figure 5. Selective covering (by tarp) or rerouting storm water around impacted bedrock will be performed if impacted bedrock areas can not be removed before the start of the rainy season. Permanent sealing of bedrock will only be considered if no other option is available. If necessary, sealing will involve the manual application of an environmentally appropriate and durable sealant. It is emphasized that any actions implemented in the bedrock areas will be done so in a manner such that no incidental take of Santa Susana Tarplant will occur.

3. If necessary, selectively remove sediments from reaches of the lower Happy Valley drainage as indicated by leachate sample results and/or simulated rainfall sample results that are

greater than the AL. Based on the data collected to date, no areas of perchlorate greater than the AL have been identified in the lower reach of the drainage.

4. Implement storm water drainage controls to route surface water runoff away from excavations in the event of a significant rainfall event (25-year, 24-hour storm). It is anticipated that a combination of sandbags and earthen dikes will be used to prevent storm water runoff from entering the excavations. Tarp may be used during a rainfall event to isolate contaminated soils and sediments from storm water contact. All excavation activities are planned for completion prior to the start of the 2003/2004 rainy season. Storm water drainage and erosion control measures will be described in a project-specific Storm Water Pollution Prevention Plan.

5. Soil and sediment excavated from the Happy Valley drainage will be transported to the Building 359/Building 325 area and either placed in bins or spread on a tarp or other suitable impermeable membrane, or transported offsite to an appropriately licensed waste disposal facility. If the material excavated from the Happy Valley drainage is transported to the Building 359/Building 325 area, the material will be spread in a layer less than 3 feet thick and bioremediated using *ex situ* composting techniques (see Section 4).

6. Performance assessment and confirmation sampling will be performed as described in Section 3.3 below following the initial excavation of material. After the performance criteria are satisfied, and prior to backfilling with clean material, those excavations in soil and sediment that are 2 feet deep or greater may receive a layer of a *in situ* biotreatment agent as suggested by bench-scale testing that is currently being performed. The biotreatment agent will provide native bacteria present in the soil and sediment with a carbon source (electron donor) to foster the right conditions for anaerobic degradation of residual perchlorate that may be present. This is intended to be a polishing step following the primary removal action. Some portions of the drainage that were excavated will be backfilled with clean fill, as appropriate. All backfill materials will meet RWQCB requirements as specified in the May 1996 *Interim Assessment and Cleanup Guidebook*.

7. Construct a temporary storm water retention structure near PZ-74 to provide for storm water and sediment capture and testing (Figure 5). This retention structure will be installed concurrently with the primary excavation and testing activities to allow for performance sampling upstream of the current surface water monitoring point HV-1. The retention structure at PZ-74 will capture some portion of the storm water runoff and allow testing of natural storm water runoff and sediments downstream of the identified perchlorate source area. The retention structure will be designed to retain approximately 50,000 gallons of storm water. Based on SSFL records, United States Geological Survey (USGS) runoff regression modeling, and regional hydrographs, the 2-year, 24-hour storm in the Happy Valley drainage at PZ-74 is estimated to convey an average flow of 200 gallons per minute (gpm) and a peak flow of approximately 750 gpm (USGS 1977, Los Angeles Department of Public Works 1991). Storm flows that exceed the capacity of the retention system would be by-passed through a spillway consisting of a vertical pipe connected to a pipe that passes beneath the embankment of the retention structure. Because of the design of the spillway structure, the pool depth of the retention structure would not exceed 5 feet. The retention

structure may be constructed as an earthen embankment or alternatively as a water-filled dam or barrier (such as that manufactured by Aqua-Barriers ™).

3.2 INTERIM MEASURE PERFORMANCE ASSESSMENT

The goal of the Happy Valley drainage interim measure actions is to reduce perchlorate in soil, sediment, and bedrock so that surface water runoff concentrations are less than the AL (4 µg/L). The following actions will be conducted to evaluate the effectiveness of the interim measures performed in the Happy Valley drainage as described above.

1. Conduct simulated rainfall and sediment leachate sampling in both the upper and lower reaches of the Happy Valley drainage following the excavation activities.

2. In the upper reach of the Happy Valley drainage, water from a nearby fire hydrant with a dispersion head will be used to wet the excavation areas as simulated rainfall. Runoff will be captured and sampled from behind temporary dams constructed downstream using sandbags and plastic sheeting.

3. Five temporary sampling dam locations are likely: 1) immediately below the source area above the rocky outcrop; 2) near PZ-117 below the rocky outcrop; 3) near HVLS35; 4) below HVLS37; and 5) near the HV-1 monitoring point.

4. Water that accumulates behind the temporary sampling dams will be pumped into a portable storage tank, and a water sample will be collected from the tank and analyzed for perchlorate to determine if treatment is necessary.

5. If treatment is required as indicated by sampling results (i.e., >4 µg/L perchlorate), the water will be processed through an ion exchange treatment unit, and sampled to confirm that the AL is met. If the AL is not achieved, then the treatment design will be modified, and samples recollected during subsequent performance testing events until treatment is proven effective.

6. In the lower reach of the Happy Valley drainage, water will be provided directly to the channel excavations via a pipeline/hose. Temporary sampling dams will be constructed, as described above, downstream of the excavations prior to the application of water. The same capture, sampling, and treatment, if necessary, of the water from the drainage will be performed as described above.

7. Verification leachate soil samples will be collected and analyzed for perchlorate from the bottom and sides of the excavated areas following excavation. The simulated rainfall sampling process will be the final verification tool. Additional sediment leachate samples will also be collected up- and downstream of the excavations.

3.3 POSSIBLE ADDITIONAL INTERIM MEASURES AND CRITERIA FOR IMPLEMENTATION

Because samples are still being collected and analyzed at the time of this work plan submittal, and further performance sampling will be conducted as outlined above, additional measures may be considered to reduce perchlorate in surface water runoff in the Happy Valley drainage. These actions and criteria for implementation may include:

1. If simulated rainfall or leachate sample results yield perchlorate concentrations greater than the AL, additional excavation may be warranted. The extent of additional proposed excavation will be determined based on sampling results.

2. If additional excavation is performed, additional performance sampling and analysis will be performed as described above in Section 3.2 to evaluate its effectiveness.

3. If perchlorate concentrations are detected in surface water runoff at concentrations greater than the AL throughout the first wet weather season, additional interim measures may be conducted the following dry weather season. The cause of the exceedance will be evaluated, discussed with DTSC, and additional measures implemented upon DTSC approval. The additional measures that may be considered include:

    - Additional sampling and excavation of perchlorate source areas (any location, including behind retention basin)
    - Conduct site-specific hydrologic analysis
    - Redesign temporary retention basin at PZ-74, or install other basins as necessary. Other basin locations that may be considered are near PZ-117 and/or PZ-123.
    - Capture and treat storm water runoff prior to discharge into drainage
    - Conduct *in situ* treatment in portions of the drainage (using methodology described below in Section 4).

4.0 PROPOSED INTERIM MEASURE ACTIVITIES NEAR FORMER BUILDING FOUNDATIONS WITHIN THE BUILDING 359 AND HAPPY VALLEY AREAS

Based on the sampling data collected to date, these areas are in and around the foundations of Building 359, Building 325, Building 376, Building 316, Building 745, and down-gradient areas that convey surface water runoff from these areas (Figure 3). In general, the interim measures for these areas are designed to either biodegrade perchlorate *in situ* or to remove the contaminated soil via excavation for offsite disposal at an appropriately licensed waste disposal facility. Excavation and offsite disposal may be specifically indicated when other COPCs, such as metals, are also present with perchlorate since metals persist under conditions favorable for the biodegradation of perchlorate. Case studies that demonstrate the effectiveness of *in situ* bioremediation as applied to perchlorate are provided in Appendix B.

A decision tree that describes the rationale for the interim measures proposed for implementation near the building foundations is presented as Figure 6. Criteria for action for the various potential interim measure activities are summarized in Table 4. Figure 7 shows the locations of potential interim measures to be implemented near the building foundations listed above.

4.1 LABORATORY AND PILOT FIELD TESTS FOR *IN SITU* BIOTREATMENT APPLICATIONS

Laboratory treatability testing is underway to evaluate the efficacy of biodegrading perchlorate initially present at low concentrations (<500 µg/kg) in soils from the SSFL (Appendix C). Specific objectives of the laboratory testing are to:

1. Demonstrate that low concentrations of perchlorate in soil can be biodegraded by the simple addition of water and an electron donor biotreatment substance (e.g., citric acid, ethanol, etc.).

2. Evaluate whether electron donor biotreatment amendments interfere with the analytical test method for perchlorate, yielding laboratory practical quantitation limits (PQLs) that are higher than desirable (i.e., higher than 40 µg/kg for soil or 4 µg/L for leachate).

3. Evaluate the lowest perchlorate concentration that can be achieved via treatment with a particular electron donor source amendment.

4. Evaluate the rate that biodegradation of perchlorate occurs for various electron donor amendments.

5. Develop design data for application in field trials of *in situ* soil treatment and/or *ex situ* soil composting.

The overall objective of the laboratory test program is to define a process that can be deployed in the field that reduces perchlorate concentrations in soil at a reasonable rate (i.e., defined as within approximately one year). If laboratory data demonstrate that perchlorate concentrations are measurably reduced during the 4 to 8 week test period at a rate that can mitigate concentrations of perchlorate detected in soil at SSFL in approximately one year, field trials will be initiated. Mitigation is defined as a perchlorate concentration in soil sufficiently low that it does not yield concentrations in surface water runoff in excess of the AL (4 µg/L). Field trials will be conducted to verify that the methods suggested by laboratory testing can be applied in a less controlled setting with similarly effective results, and to refine the methodology for full-scale application. Specific details to evaluate and refine with the field trials include methods for soil moisture control and measurement, and methods to distribute the biotreatment materials to the surficial soils.

4.2 FULL-SCALE BIOTREATMENT APPLICATION, LOCATION, AND DESIGN

Following successful completion of the laboratory test and field trial of *in situ* bioremediation of perchlorate in SSFL soils, full-scale implementation of biotreatment will proceed at those locations in the subject area where the only chemical of potential concern is perchlorate. At those locations where soil chemistry data indicates that other COPCs (e.g., metals) are also present at concentrations that may pose an unacceptable risk to human health or the environment, the soils will be excavated and transported offsite for disposal. The proposed treatment and excavation areas are shown on Figure 7.

The areas proposed for *in situ* treatment have been identified as 'perchlorate source areas' if they contain several concentrations of perchlorate that appear to contribute to surface water runoff at concentrations greater than the AL (Figures 3 and 7). Based on the distribution of current sampling results, the 'trigger level' concentration in the Building 359 area is assumed to be about 20 µg/L in soil leachate. This trigger value may be modified after further sampling data are collected since the relationship between soil leachate or simulated rainfall samples to natural

storm water runoff conditions is not well understood. Changes to criteria will be discussed with DTSC prior to implementation.

Two types of full-scale biotreatment design will be implemented: *in situ* biotreatment of soil, and *ex situ* composting of soil. As described in Section 3, it is likely that excavated material from the Happy Valley drainage will be spread on a tarp or other appropriate impermeable membrane overlying an *in situ* biotreatment location in the Building 359/Building 325 area, and biotreated *ex situ*. For purposes herein, it is assumed that *ex situ* composting of excavated material from the Happy Valley drainage will be conducted with similar treatment agents, and in conformance with similar performance monitoring requirements as that described below for the *in situ* biotreatment approach. The primary difference between the *in situ* and *ex situ* biotreatment approaches is that the *ex situ* biotreatment method will allow for the biotreatment agent to be blended with the excavated material to be treated as opposed to its application topically.

In general, *in situ* biotreatment will involve the following:

1. Apply an appropriate electron donor biotreatment material, as indicated by the laboratory and field trials, to the surface of the ground in the areas to be treated. An organic material, such as straw or wood chips, may be applied over the top of the treatment agent, and the entire area watered to near saturation. The objective is to create anaerobic conditions so that native bacteria chemically reduce the perchlorate.

2. Monitor the moisture content of the surficial soils, and add water to maintain the near-surface moisture content near field capacity (the amount of water that can be retained in the soil without continued leaching). The objective is to provide the maximum amount of moisture possible without the potential for leaching surface perchlorate to greater soil depths.

3. During the wet weather season, cover the treatment area with tarps to prevent storm water from contacting the perchlorate contained in the treatment zone, and leaving the RFI site as runoff. Tarps must be weighted down using sandbags or another acceptable method. Use sandbags, earthen dikes, or straw bales to construct temporary surface water diversions to prevent run-on to the treatment area during storm events.

4. The sampling schedule will be dictated by the results of the bench scale testing. The initial sampling will be performed after sufficient time has elapsed to expect that the performance objectives have been met. This is anticipated to be within 30 days. At this time, composite soil samples will be collected from the treatment zone for perchlorate analysis to quantify treatment progress. If reduction in the perchlorate concentration is not proceeding at a measurable and acceptable rate, evaluate and revise the design of the treatment protocols.

Continue with treatment. If evaluation of the treatment methodology indicates that treatment can not likely be accelerated towards a completion time of 1 year by modifying the treatment protocols, terminate the treatment program. Excavate the subject soils for transportation offsite to an appropriately licensed waste disposal facility.

5. After 6 and 12 months of treatment, collect composite soil samples from the treatment zone for leachate analysis for perchlorate to quantify treatment progress. At 6 months, review results with DTSC and if considered favorable, establish interim completion criteria, and continue treatment. At 12 months, sample and review results with DTSC. If treatment is deemed to be inadequate, evaluate additional interim measures, to include additional biotreatment, or excavation and offsite disposal.

4.3 INTERIM MEASURE PERFORMANCE ASSESSMENT

Two types of interim measures may be implemented in the subject areas: 1) *in situ* or *ex situ* biotreatment of excavated material that contains perchlorate; and/or 2) excavation and offsite disposal of excavated material that contains perchlorate and/or other COPCs. The goal of the interim measure actions near former building foundations is to reduce perchlorate in soil and sediment so that surface water runoff concentrations are less than the AL (4 µg/L). Assessment of the performance of these two types of interim measures will be performed as follows:

1. Collect composite samples of soil, sediment, and/or rock from *in situ* and *ex situ* biotreatment areas periodically for chemical analysis of perchlorate contained in the solid matrix as well as leachate. Each composite sample will be prepared by combining 5 individual soil samples collected from various depths within a treatment area about 50 by 50 feet in size. If some treatment areas are smaller in size, a minimum of 3 individual samples will be collected. Each composite soil sample will be analyzed for perchlorate, moisture, nitrate, sulfate, and total organic content. A soil leachate sample will also be prepared from the composite soil sample and analyzed for perchlorate. At a minimum, collect samples for chemical analysis at the initiation of treatment, after 30-days, and at 3-month intervals thereafter.

2. In those areas where materials are excavated and transported offsite for disposal at an appropriately licensed waste disposal facility, collect soil and leachate samples from the bottom and the sidewalls of the excavation. Confirmation samples will be analyzed for perchlorate and other identified COPCs. Confirmation sample target levels will be determined in consultation with DTSC after performance samples are collected and analyzed, and other COPCs are identified. Excavation will proceed until agreed upon confirmation sample target concentrations are achieved.

3. Following significant storm events, collect storm water runoff samples from drainages leading from the RFI site and chemically analyze the samples for perchlorate. The objective is for storm water runoff to be less than the surface water AL.

4. Compare the mean perchlorate concentrations of composite samples collected from the biotreatment areas at three-month intervals to evaluate that perchlorate concentrations in soil are being reduced measurably, and at a reasonable rate. Adjust the biotreatment process, if appropriate, to attempt to accelerate the rate of biodegradation.

5. After 6 months of treatment, review biotreatment progress with DTSC. Continue, adjust, or terminate biotreatment as indicated by the demonstrated progress to date, and the status of perchlorate concentrations in the treatment zone. The objective is for the biotreatment process to complete treatment within 1 year. If favorable, establish interim measure completion criteria with DTSC.

6. After 12 months of treatment, if treatment is still ongoing, review biotreatment progress with DTSC. Continue, adjust, or terminate biotreatment as indicated by the demonstrated progress to date, and the status of perchlorate concentrations in the treatment zone.

4.4 POSSIBLE ADDITIONAL INTERIM MEASURES AND CRITERIA FOR IMPLEMENTATION

Because samples are still being collected and analyzed at the time of this work plan submittal, and further performance sampling will be conducted as outlined above, additional measures may be considered to reduce perchlorate in surface water runoff near former building foundations in the Happy Valley and Building 359 areas. These actions and criteria for implementation may include:

1. Implement full-scale treatment if additional perchlorate source areas are identified with no other COPCs. If other COPCs are contained within the treatment area that may pose a risk to human health or the environment, excavate those areas for offsite disposal at an appropriately licensed waste disposal facility.

2. If at any time during implementation of the biotreatment process, performance monitoring data suggest that the rate of biotreatment can not be maintained or accelerated to complete treatment within 1 year, soil that contains perchlorate at concentrations above DTSC-approved levels may be excavated for offsite disposal at an appropriately licensed waste disposal facility. Collect soil and leachate samples from the bottom and the sidewalls of the excavation; establish confirmation sample requirements with DTSC.

3. Following completion of biotreatment and/or excavation, if perchlorate concentrations are detected in surface water runoff at concentrations greater than the AL throughout the first wet weather season, additional interim measures may be conducted the following dry weather season. The cause of the exceedance will be evaluated, discussed with DTSC, and additional measures implemented upon DTSC approval. The additional measures that may be considered include:

- Sampling to identify additional perchlorate source areas
- Excavation (any location, including within in situ treatment areas)
- Conduct site-specific hydrologic analysis

5.0 SUMMARY OF HAPPY VALLEY INTERIM MEASURES

Interim measures to be implemented in the Happy Valley and Building 359 areas are designed to control the release of perchlorate in soil, sediment, and bedrock to surface water. The objective is to reduce the amount of perchlorate contacting storm water so that surface water concentrations comply with the proposed water quality objective, assumed in this work plan to be 4 µg/L.

Phase I of the HVIM will be implemented in areas that will not adversely impact Santa Susana Tarplant. Phase II will implement measures after a special permit for removal of Santa Susana Tarplant is obtained from the CDFG.

The primary proposed interim measures include a combination of excavation and *ex situ* biotreatment or offsite disposal, and *in situ* biotreatment. Proposed HVIM actions are summarized in Table 5. The locations of proposed HVIM actions are shown on Figures 5 and 7.

In the following sections, the scope of the HVIM actions and a tentative schedule are described.

5.1 SCOPE OF HVIM ACTIONS

There are two categories of HVIM actions: 1) primary HVIM actions that are designed for implementation prior to the rainy season to control the release of perchlorate to surface water; and 2) additional HVIM actions that may be implemented should the primary HVIM actions not achieve performance standards. It is emphasized that investigations are ongoing, and that additional interim measures may be warranted in new locations pending the results of sampling and analysis.

The primary HVIM actions include:

- Excavate an estimated 1100 to 1500 cubic yards of soil and sediment from the source area and the upper reach of the Happy Valley drainage. Excavated materials are to be

either transported to the Building 359/Building 325 area for *ex situ* composting or transported offsite for disposal.

- If deemed to be a critical contributor to surface water, remove the upper 2 to 4 inches of bedrock that contains perchlorate in the upper reach of the Happy Valley drainage; cover or reroute storm water around these areas if removal not possible prior to the rainy season.
- Install a temporary surface water retention basin near PZ-74 to contain storm water runoff for sampling and analysis downstream of the excavation area within the drainage.
- Perform *in situ* biotreatment of perchlorate contained in surficial soils near the foundations of Building 745, Building 316, Building 376, and Building 359/325.
- Excavate and transport for offsite disposal soils that contain metals near the northern portion of the Building 325 area, and the Building 316 area.

The additional HVIM actions may include:

- Conduct additional sampling to identify perchlorate source areas; excavate or conduct *in situ* or *ex situ* bioteatment to reduce perchlorate concentrations.
- Conduct site-specific, detailed hydrologic analysis of the impacted areas.
- Redesign the temporary surface water retention basin at PZ-74, or install additional basins.
- Capture and treat surface water behind the temporary retention basin(s).

5.2 SCHEDULE OF HVIM ACTIONS

Continued characterization sampling for refinement of the HVIM is ongoing. Implementation of the HVIM will begin as soon as DTSC approves this Amendment, CDFG, ACOE, and RWQCB approve permits, and sampling data are reviewed. It is desired to begin implementation activities as soon after September 1, 2003 as possible. If work begins by early- to mid-September, all construction activities outlined herein can be completed by the predicted start of the 2003/2004 rainy season (November 2003).

HVIM implementation and performance sampling will be reviewed with DTSC throughout the project, and modifications to scope made as necessary. Completion of the HVIM is anticipated within one year, although if additional measures are required this may not be possible. Results of the HVIM activities will be documented in an HVIM Report as an addendum to the RFI site report to be prepared after the HVIM completion is agreed upon with DTSC.

6.0 REFERENCES

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Table 1 (Page 1 of 3)

Description of Buildings, Chemical Use Areas, and Soil Sampling Results Summary at the Happy Valley RFI Site

Building/Area	Former Use and Characteristics	Sampling Rationale	Summary of Preliminary Soil Sampling Results
Building 315	Formerly a chemistry laboratory used in support of engine testing at sites in Area I. The building and the adjacent concrete-lined, covered sump were used for propellant explosive tests. The building was later used as a diagnostic optics laser laboratory.	Analyze soil vapor samples from within and around building for solvents. Analyze sump contents and surrounding soils for VOCs, SVOCs, TPH, metals, pH, and ordnance. Analyze surface water runoff sample downslope (north) of building for perchlorate.	VOCs detected below FALs (up to 2.4 µg/Lv) in soil vapor adjacent to the sump. Freon 113 detected up to 9.1 µg/Lv southeast of the building. Lube oil-range TPH (up to 250 mg/kg) and several metals detected above FALs in sump contents. TPH (up to 21,000 mg/kg gasoline-range), metals (most commonly arsenic, up to 63 mg/kg) and VOCs (up to 8,000 mg/kg 1,2-Dichlorobenzene) detected above FALs in surrounding soils. Perchlorate not detected in surface water sample.
Buildings 316 and 346	Happy Valley Tunnel Facility. Rocket and gun propellants (including turbine spinners containing perchlorate) were tested inside the enclosed Tunnel facility adjacent to Building 316. Behind the building was an incinerator in which trash and paper, possibly containing propellant residues, were burned. Live rounds for gun tunnel operations were stored in Building 346.	Analyze soil vapor samples from around building for solvents. Analyze incinerator contents for SVOCs, metals, pH, dioxins, PCBs, perchlorate, hexavalent chromium, anions, and formaldehyde. Analyze area soils for SVOCs, metals, pH, and dioxins. Analyze surface water sample downslope of buildings for perchlorate.	Freon 113 detected above FAL in soil vapor (up to 810 µg/Lv) near Building 316. Dioxins, lead (up to 92 mg/kg), arsenic (up to 71 mg/kg), and PCBs (Aroclor 1016 at 1600 µg/kg) detected above FALs in incinerator contents. Perchlorate detected above FAL (up to 0.1 mg/kg) in surface sediment and soil adjacent to Building 316 and incinerator. Metals (primarily arsenic, lead, mercury, and zinc) detected above FALs in soil throughout the area. Highest arsenic detected (110 mg/kg at 0.5 feet bgs) on slope south of former Tunnel Facility. Perchlorate detected in one surface water runoff sample (11 µg/L) collected downslope from Building 316.
Building 372, containment sumps, and downslope natural drainage	Building 372 is referred to as “Oxidizer quick mix cells” on historical facility maps. During the 1960s the building was used for flare research, development, and production. Perchlorate was mixed/processed in cells on the sides of the building. From the 1970s through 1993, the building was used for gun propellant research and development. Discharge from the operations collected in two sumps located on the southwest and southeast corners of the building. Each sump discharged through pipelines that led to a sump pump located south of the building adjacent to the drainage. The sump discharged the wastewater via a steel pipe into an eastern drainage leading to Canyon test area ponds.	Analyze soil vapor samples around building for solvents. Analyze sump contents and downslope soils for VOCs, SVOCs, TPH, metals, ordnance, pH, hexavalent chromium, perchlorate, and anions. Analyze soil matrix and leachate samples for perchlorate from locations surrounding the former building and in the downslope drainage. Analyze surface water for perchlorate from the former concrete floor, locations surrounding the former building and in the downslope drainage, and from storm events.	Freon 113 detected below FAL (up to 2.2 µg/Lv) in 1993 soil vapor sample (only VOC detected in soil vapor). Acetone, 1,2-DCE, saturated aliphatic hydrocarbons, and ‘unknown hydrocarbons’ detected below FALs in 1993 soil matrix sample near west sump. Ordnance (up to 16,000 µg/kg RDX) and perchlorate (0.04 mg/kg) detected above FALs in sump contents. TRPH (up to 250 mg/kg) and several metals (antimony up to 10 mg/kg, lead up to 208 mg/kg, and mercury up to 0.39 mg/kg) detected above FALs in soils adjacent to sumps. Beryllium (0.97 mg/kg) detected above FALs in soils north of former Building 372 foundation. In soils downslope (south-southeast) of Building 372, cadmium (up to 8.8 mg/kg), lead (46 mg/kg), and mercury (up to 20.5 mg/kg) detected above FALs. TPH (up to 97 mg/kg lube oil-range), VOCs and ordnance detected below FALs. These soils subsequently removed during 1999 IM. Perchlorate detected up to 100 mg/kg in concrete samples collected from the building. Perchlorate detected in surface water on the former foundation at 58 µg/L (380 µg/L in artificial surface water). Perchlorate concentrations typically range from 20 to 75 µg/L (up to 630 µg/L) in surface water collected in upper portion of the drainage.

Table 1 (Page 2 of 3)

Description of Buildings, Chemical Use Areas, and Soil Sampling Results Summary at the Happy Valley RFI Site

Building/Area	Former Use and Characteristics	Sampling Rationale	Summary of Preliminary Soil Sampling Results
Building 385	Former igniter storage (originally identified as energetic materials storage)	Analyze soils downslope from former building for SVOCs, metals, pH, and ordnance. Analyze soil samples for perchlorate near building foundation.	Beryllium (up to 77 mg/kg), lead (up to 60 mg/kg), and silver (up to 3.28 mg/kg) detected above FALs. SVOCs and ordnance detected below FALs. Perchlorate data pending.
Building 745	Motor Test Facility/ Solid Propellant Test building. Static testing of solid rocket propellants occurred in an open-walled, awning covered structure (Building 745). Test articles were fix-mounted while the test propellant was ignited; time and pressure characteristics were measured during testing.	Analyze soil vapor samples for solvents. Analyze soils adjacent to and downslope from former areas for perchlorate, TPH, metals, and pH. Soils near Building Area 745 also analyzed for VOCs, anions, and ordnance. Analyze soil leachates and a surface water sample from near Building 745 for perchlorate.	Maximum VOC detected in soil vapor was TCE at 1.4 µg/Lv. Only VOCs detected were chloroform and TCE. VOCs, metals, TPH, and ordnance not detected in soils near Building 745. Perchlorate detected at 50 µg/kg in soil, and up to 81 µg/L in soil leachates collected near Building 745. Perchlorate not detected in surface water collected downslope from 745.
Building 706	Former Tank Area	Analyze soils adjacent to and downslope of former tank pad for perchlorate, TPH, metals, and pH.	TPH only detected above FAL (up to of 160 mg/kg lube oil) in a soil sample collected near former Building 706 foundation. Silver (up to 4.2 mg/kg), beryllium (up to 2.3 mg/kg), and lead (up to 35 mg/kg) detected above FALs. No metals detected above FALs in samples collected further downslope. Perchlorate detected at 5 µg/L in leachate sample downslope of area.
Building 447, Area 917 and Gun Range Backstop	Building 447 was used as a gun propellant storage area for the adjacent shooting range. Area 917 was the gun mount area. Guns were fired to the east into an earthen backstop area.	Analyze surface soil sample from within backstop area for lead and pH. Analyze surface water runoff samples downslope for perchlorate.	Lead detected above FAL (40 mg/kg) in surface sample. Lead not detected in deeper sample collected at 5 feet bgs. Perchlorate detected up to 17 µg/L in surface water samples collected in drainage downslope from former backstop area.
Building 406	Propellant fabrication laboratory	Analyze soil samples from trenches in drainage downslope of building for perchlorate. Analyze leachates of lateral composite soil samples around building (and vertical soil boring leachate samples in downslope drainage) for perchlorate.	Perchlorate not detected in soils from trenches. Perchlorate detected up to 66 µg/l in soil leachate samples around building foundation.

Table 1 (Page 3 of 3)

Description of Buildings, Chemical Use Areas, and Soil Sampling Results Summary at the Happy Valley RFI Site

Building/Area	Former Use and Characteristics	Sampling Rationale	Summary of Preliminary Soil Sampling Results
Buildings 365, 394, 395, and 616	Former Class A explosive storage magazines for ordnance or propellants.	Analyze surface water samples downslope from magazines for perchlorate.	Perchlorate not detected in surface water samples collected downslope in drainage.
Building 988	Curing and hardening of propellants.	Analyze shallow soil sample near former structure for perchlorate.	Perchlorate not detected. Soil leachate sample data pending.
Building 387	Propellant (pellet) press building. Propellants were pressed into predetermined shapes and sizes for later use in various test articles.	Analyze surface sediment on foundation for metals and perchlorate. Analyze downslope soil samples for metals, pH, and perchlorate. Analyze lateral leachate soil samples around former building for perchlorate.	Beryllium (up to 16 mg/kg), lead (up to 40 mg/kg), and silver (up to 5 mg/kg) detected above FALs in soils within approximately 25 feet downslope of former building. Other metals not detected above FALs. Except for aluminum (below FAL), no metals detected in surface sediments on building foundation. Perchlorate detected at 27 µg/L in leachate sample, but not detected in sediment or soil samples. Surface water collected in drainage downslope from the building did not contain detectable perchlorate.
Building 340	Propellant processing	Analyze soil vapor samples for solvents. Analyze soil adjacent to and around former building foundation for VOCs, SVOCs, TPH, metals, pH, hexavalent chromium, ordnance, perchlorate, and anions. Analyze lateral leachate soil samples for perchlorate.	VOCs not detected in soil vapor. Mercury (1 mg/kg) detected above FALs adjacent to building, but not in downslope soil sample. Lead detected above FAL at 26 mg/kg in downslope sample. Perchlorate detected in 1 of 3 leachate samples at 9 µg/L.
Building 390	Control center for operations at the solid propellant test pad in Area 745	Building not targeted; no documented chemical use.	N/A

Notes
(1) Most buildings constructed during the 1950s and inactive by 1993/1994.
(2) RFI characterization is ongoing and sampling data is being reviewed. The sampling results summarized here should be considered preliminary until the draft RFI site report is published.
(3) Site characterization during Interim Measures has targeted all former buildings at the site.
Sources: MWH 2003a, Ogden 1996 and 1999, facility records.
:

N/A = Not Applicable
SVOC = Semivolatile Organic Compound
TCA = Trichloroethane
VOC = Volatile Organic Compound
mg/kg = milligrams per kilogram
µg/L = micrograms per liter
FAL = Field Action Level
IM = Interim Measure
TPH = Total Petroleum Hydrocarbons
TCE = Trichloroethene
SV = soil vapor
bgs = below ground surface
µg/Lv = micrograms per liter vapor

Table 2 (Page 1 of 2)

Description of Buildings, Chemical Use Areas, and Soil Sampling Results Summary at the Building 359 Area RFI Site

Building/ Area	Former Use and Characteristics	Sampling Rationale	Summary of Preliminary Soil Sampling Results
Building 359 and sump	Building 359 was primarily used for energetic materials testing. Test cells along the northern side drained to a 2' x 2' x 2' sump located on the north side of the building. The sump drained via an underground pipe to a concrete-lined ditch along the Area I Road. Testing was not performed on the south side of the building.	Analyze soil vapor samples near sump and surrounding building for solvents. Analyze sump liquids, sediments, and surrounding soils for metals, ordnance, VOCs, SVOCs, TPH and perchlorate. Analyze soil leachates and surface water runoff for perchlorate surrounding and downslope from building and sump.	Only low concentrations of VOCs detected in soil vapor (up to 55 µg/Lv Freon 113 and 39 µg/Lv TCE). VOCs (primarily TCE and 1,1,1-TCA), metals (various, including mercury), lubricant oil-range TPH, SVOCs (primarily bis [2-Ethylhexyl] phthalate, and perchlorate detected above FAL in sump liquids and sediments. Primarily perchlorate (up to 4.66 mg/kg), arsenic (up to 94 mg/kg), and mercury (up to 1.3 mg/kg) were detected above FALs in soils surrounding sump and to west side of building. Hexavalent chromium, lubricant oil-range TPH, and lead were also detected above FALs in surrounding soils.
Building 325/ Building 349	Building 325 was used for perchlorate mixing, milling, and physical/chemical characterization for rocket engine igniters and propellants. Building 349 is shown adjacent to Building 325 on historical facility maps. Specific use not documented.	Analyze soil vapor samples for solvents. Analyze soil samples from around the former building for metals and perchlorate. Analyze soil leachates, surface water from the former foundation, and downslope runoff for perchlorate.	VOCs not detected in soil vapor. Perchlorate and arsenic detected above FALs in soil matrix samples (up to 0.22 mg/kg perchlorate and 18 mg/kg arsenic). Perchlorate detected up to 0.16 mg/L in soil leachate samples adjacent to building. Perchlorate detected up to 570 µg/L in surface water collected from the Building 325 foundation, and up to 97 µg/L in concrete-lined channel northwest of the former buildings.
Building 376, Area 743, and Area 997	These areas were primary perchlorate storage and handling areas. Building 376 was used for oxidizer preparation. Area 743 was a concrete storage dock used for drum loading and storage operations. Area 997 was an oxidizer storage shed.	Analyze soil samples around the former building for perchlorate. Analyze soil leachates and surface water samples around the former building and dock area for perchlorate.	Perchlorate detected above FAL in soil matrix samples (up to 71 mg/kg). Perchlorate detected in soil leachate samples (up to 10 mg/L). Surface water runoff contained perchlorate (up to 170 µg/L).
Area 741	Igniters were tested in small test cells that faced east.	Analyze soil vapor samples for solvents. Analyze soil samples adjacent to and downslope of the former area for perchlorate. Analyze soil leachate samples adjacent to and downslope of the former area for perchlorate.	Only VOCs detected in soil vapor were Freon 113 and TCE (up to 22 µg/Lv Freon 113). Perchlorate detected above FAL in soil matrix sample (0.06 mg/kg at 2 feet bgs), and at 0.01 mg/L in soil leachate samples.

Table 2 (Page 2 of 2)

Description of Buildings, Chemical Use Areas, and Soil Sampling Results Summary at the Building 359 Area RFI Site

Building/ Area	Former Use and Characteristics	Sampling Rationale	Summary of Preliminary Soil Sampling Results
Building 328/723	Building 328 was used as a propellant press building. Propellants were pressed into predetermined shapes and sizes. Building 723 was used for chemical storage.	Analyze soil vapor samples for solvents. Analyze soils adjacent to building for perchlorate.	Freon 113 detected up to 22 µg/Lv in sample north of Building 723. Perchlorate not detected in soil adjacent to building. Samples also analyzed for lead and mercury as step out samples from building 362. Lead detected above FAL at 33 mg/kg. Mercury not detected.
Buildings 400, 373, and sumps	Building 400 was used for peroxide drum storage. Building 373 was possibly a small-scale laboratory. Two collection sumps were located northwest of Building 400.	Analyze soil vapor samples for solvents. Analyze sump contents for VOCs, SVOCs, metals, and TPH. Analyze soil samples from lined ditches for metals.	TCE detected at 1.9 µg/Lv in soil vapor near sumps. Metals and SVOCs detected above FALs in sump contents. Lead (up to 84 mg/kg), mercury (up to 2.9 mg/kg), and beryllium (up to 1.0 mg/kg) detected above FALs in soils downslope from sumps.
Buildings 404 and 362	Buildings used for instrument and hardware storage.	Buildings not targeted for sampling due to no recorded chemical use. Results of step out sampling for TPH, metals, and SVOCs (based on nearby sump results) presented above (Buildings 328/723).	N/A
Leach field (partially under former concrete pads in northeast)	Sanitary leach field possibly from Building 301.	Analyze soil vapor samples for solvents. Sample inlet and downgradient area for TPH and metals.	VOCs not detected in soil vapor. Metals detected above FALs: primarily barium (up to 6,875 mg/kg), copper (up to 232 mg/kg), lead (up to 718 mg/kg), silver (up to 604 mg/kg), and zinc (up to 5974 mg/kg) TPH detected up to 61 mg/kg (lubricant oil-range).

Notes:
(1) Most buildings constructed during the 1950s and inactive by 1993/1994.
(2) RFI characterization is ongoing and sampling data still being reviewed. The sampling results summarized here should be considered preliminary until the draft RFI site report is published.
(3) Site characterization during Interim Measures has targeted all former buildings at the site.
Sources: MWH 2003a, Ogden 1996 and 1999, facility records.

N/A = Not Applicable
SVOC = Semivolatile Organic Compound
TCA = Trichloroethane
VOC = Volatile Organic Compound
TPH = Total Petroleum Hydrocarbons
TCE = Trichloroethene
mg/kg = milligrams per kilogram
µg/L = micrograms per liter
µg/Lv = micrograms per liter vapor
FAL = Field Action Level

Table 3
Criteria for Interim Measure Activities in the Happy Valley Drainage
(Page 1 of 1)

Interim Measure Activity	Criteria for Action
Excavate Sediments, Soil	Sediment leachate or simulated rainfall samples > AL And Work can be completed before predicted start of 2003 rainy season
Excavate Bedrock Surface	Removal feasible based on absence of Santa Susana Tarplant And Area considered critical contributor to surface water concentrations > AL
Apply temporary covers and/or create storm water diversions	Excavation not feasible due to predicted start of rainy season or location of Santa Susana Tarplant And Area considered critical contributor to surface water concentrations > AL
Backfill with clean sediment/soil	Excavation requires backfill as specified in permits (as appropriate)
Construct Temporary Storm Water Retention Structure Near PZ-74	Provide structure for storm water / sediment retention and testing
Construct Temporary Storm Water Retention Structure Near PZ-117	Majority of confirmation samples from area upstream of PZ-117 (simulated rainfall or leachate) > AL And Additional excavation not possible to complete by predicted start of 2003 rainy season And High possibility based on professional judgement that surface water runoff at NPDES monitoring point > AL
Construct Temporary Storm Water Retention Structure Near PZ-123	Majority of confirmation samples from area between PZ-74 and PZ-123 (simulated rainfall or leachate) > AL And Additional excavation not possible to complete by predicted start of 2003 rainy season And High possibility based on professional judgement that surface water runoff at property boundary > AL
Apply *In-situ* Treatment Materials to Excavation Areas	Confirmation samples (simulated rainfall or leachate) indicate low concentrations (< AL) that could potentially contribute to surface water runoff > AL And Laboratory treatability test indicates perchlorate reduction achievable < AL And Excavation requires backfill (as required in permit)
Conduct Additional Measures – Possible Alternatives include: 1. Additional sampling and excavation (any location, including behind retention basin) 2. Conduct site-specific hydrologic analysis 3. Redesign temporary retention basin at PZ-74, or install other basins as necessary 4. Capture and treat storm water runoff prior to discharge into drainage 5. Conduct *in situ* treatment in portions of the drainage	Surface water runoff is > AL throughout 2003/2004 rainy season

Notes:

1. The surface water AL has been used as the soil leachate or surface water sample (artificial or natural) 'trigger level' for proposed interim measure actions within the Happy Valley drainage. Trigger values may be modified after the initial storm event, since the relationship between soil leachate or artificial surface water samples to natural storm water runoff conditions is not well understood based on the data available to date. Changes to criteria would be discussed with DTSC prior to implementation.
2. Simulated rain event = fire hydrant water dispersed over area of drainage to create artificial surface water (see text).
3. Leachate = water samples collected by saturating soil/sediment and decanting the liquid (see text).
4. Permanent sealing of bedrock is not planned at this time and will only be used as an interim measure if no other option is available.

AL - Surface Water Action Level, considered to be 4 ppb or the established California MCL
DTSC – Department of Toxic Substances Control
MCL – Maximum Contaminant Level
ppb – parts per billion (equivalent to micrograms per liter (ug/L), micrograms per kilogram (ug/kg)).

Table 4
Criteria for Interim Measure Activities Near Former Building Foundations
In the Happy Valley and Building 359 Areas
(Page 1 of 1)

Interim Measure Activity	Criteria for Action
Conduct Laboratory Treatability Test	Perchlorate source area exists that contributes to surface water runoff > AL
Conduct Field Pilot Test	Laboratory treatability test results indicate perchlorate reduction is measurable and occurs at an acceptable rate And Perchlorate source area exists that contributes to surface water runoff > AL And No other COPCs occur that may compromise the test effectiveness, require alternative cleanup measures, or potentially impact other media
Construct Full-Scale Bioremediation Application	Pilot field test results indicate perchlorate reduction is measurable and occurs at an acceptable rate And Perchlorate source area exists and contributes to surface water runoff > AL And No other COPCs occur that may compromise the test effectiveness, require alternative cleanup measures, or potentially impact other media
Modify Full-Scale Bioremediation Application or Consider Excavation Removal Action	Full-scale performance monitoring results at 6 months do not indicate treatment is effective And Excavation removal areas localized and activities can occur during dry season
Complete Full-Scale Bioremediation Application	IM biotreatment completion criteria are established with DTSC following 6-month application period
Cover Treatment Areas and Create Surface Water Diversions	Performance monitoring results indicate treatment not complete by predicted start of rainy season
Conduct Full-Scale Bioremediation Application in Additional Areas	Sampling results after August 12, 2003 indicate a perchlorate source area exists that contributes to surface water runoff > AL And Bench and pilot field tests indicate full-scale application warranted
Excavate soils	Concentrations of other COPCs may compromise the test effectiveness, require alternative cleanup measures, or potentially impact other media And Excavation removal areas localized and activities can occur during dry season
Conduct Additional Measures – Possible Alternatives include: 1. Sampling to identify additional perchlorate source areas 2. Excavation (any location, including within in situ treatment areas) 3. Conduct site-specific hydrologic analysis	Surface water runoff is > AL after treatment is deemed complete Or In situ treatment deemed inadequate to reduce perchlorate to surface water runoff < AL

Notes:

1. A "perchlorate source area" is defined as an area that has several detected soil or soil leachate concentrations that appear to contribute to surface water runoff > the AL. Based on distribution of existing sampling results, this 'trigger level' concentration is assumed to be about 20 ppb. This trigger value may be modified after further sampling data are collected since the relationship between soil leachate or artificial surface water samples to natural storm water runoff conditions is not well understood based on the data available to date. Changes to criteria would be discussed with DTSC prior to implementation.
2. Measurable perchlorate reduction will be determined based on soil matrix and soil leachate sample laboratory results.
3. Treatment rate will be deemed acceptable if perchlorate concentrations can be reduced within a period of about 1-year so that there is not a continuing contribution to surface water runoff greater than the AL.

AL - Surface Water Action Level, considered to be 4 ppb or the established California MCL
COPC - Chemical of Potential Concern
DTSC – Department of Toxic Substances Control
MCL – Maximum Contaminant Level
ppb – parts per billion (equivalent to micrograms per liter (µg/L), micrograms per kilogram (µg/kg)).

Summary of Proposed HVIM Actions and Extent

Table 5. Summary of Proposed Interim Measures.

Location	Activity Proposed	Estimated Area (square feet)	Estimated Volume (cubic yards)
Happy Valley Drainage			
Source Area and Upper Reach	Excavation and ex situ treatment in Building 359 location	24,200	1,100
Areas Near Building Foundations			
Building 745	In situ treatment	860	65
Building 316	In situ treatment	2,660	200
Building 316	Excavation due to elevated metals concentrations	940	70
Building 376 (Phase I and II)	In situ treatment	5,500	410
Building 359/325 (northern portion)	Excavation due to elevated metals concentrations	3,700	270
Building 359/325 (southern portion)	In situ treatment	19,300	1,430

Notes:

1. Estimated excavation and treatment volume for Happy Valley drainage area based on an average 3-foot depth in the source area and 1-foot depth in the remaining portion.
2. Estimated excavation and treatment volume near former building foundations based on an average 2-foot depth.
3. Soil and sediment from the Happy Valley Source Area and Upper Reach may be transported for ex situ composting at the Building 359/Building 325 area.

Happy Valley

Motor Test Area

Water Pipeline

Former Energetic Materials Storage

Former Control Center

Gun Range Backstop

Gun Mount Area

Former Energetic Materials Storage

Former Energetic Materials Storage

Former Energetic Materials Storage

Former Energetic Materials Storage

Propellant Press Bldg

Igniter Storage

Sumps

Sump Pump

RD-10

PZ-117

PZ-074

PZ-123

Happy Valley Surface Water Sample Location (HV-1)

Happy Valley Surface Water Sample Location (HV-2)

HVLS80

S_num/Depth	EPA Id	Perchlorate
S01 D 0.50	ML124	32 ug/l *

HVLS81

S_num/Depth	EPA Id	Perchlorate
S01 D 0.50	ML125	32 ug/l *
S05 D 5.00	ML126	< 4 ug/l U*
S06 D10.00	ML127	< 4 ug/l U*

HVLS39

S_num/Depth	EPA Id	Perchlorate
S01 D 0.04	MD021	2 ug/l J*

HVLS41

S_num/Depth	EPA Id	Perchlorate
S01 D 0.04	ML026	< 4 ug/l U*
S02 D 0.33	ML027	< 4 ug/l U*

HVLS38

S_num/Depth	EPA Id	Perchlorate
S01 D 0.04	ML018	< 4 ug/l U*
S02 D 0.33	ML019	< 4 ug/l U*
S04 D 0.04	ML020	< 4 ug/l U*

HVLS40

S_num/Depth	EPA Id	Perchlorate
S01 D 0.04	ML022	16 ug/l *
S02 D 0.33	ML023	12 ug/l *
S03 D 0.33	ML024	< 4 ug/l U*
S04 D 0.04	ML025	< 4 ug/l U*

HVLS83

S_num/Depth	EPA Id	Perchlorate
S01 D 0.04	ML130	3 ug/l J*

HVLS82

S_num/Depth	EPA Id	Perchlorate
S01 D 0.04	ML129	9.9 ug/l *

HVLS84

S_num/Depth	EPA Id	Perchlorate
S01 D 0.04	ML131	5.7 ug/l *

HVLS42

S_num/Depth	EPA Id	Perchlorate
D01 D 0.04	ML038	7.5 ug/l *
D02 D 0.33	ML040	3.3 ug/l J*
D03 D 0.04	ML042	230 ug/l *
D04 D 0.04	ML044	1.3 ug/l J*
S01 D 0.04	ML037	4.1 ug/l *
S02 D 0.33	ML039	4.7 ug/l *
S03 D 0.04	ML041	320 ug/l *
S04 D 0.04	ML043	1.1 ug/l J*
S05 D 1.00	ML045	4 ug/l J*
S08 D 2.50	ML046	< 4 ug/l U*
S09 D 3.00	ML047	2.9 ug/l J*
S10 D 3.50	ML048	< 4 ug/l U*
S99 D 0.50	MJ274	< 4 ug/l U*

HVLS35

S_num/Depth	EPA Id	Perchlorate
S01 D 0.04	ML010	< 4 ug/l U*
S04 D 0.04	ML011	1.2 ug/l J*

HVLS33

S_num/Depth	EPA Id	Perchlorate
S01 D 0.04	ML003	< 4 ug/l U*
S02 D 0.33	ML004	< 4 ug/l U*
S04 D 0.04	ML005	< 4 ug/l U*

HVLS43

S_num/Depth	EPA Id	Perchlorate
S01 D 0.04	MD049	4.4 ug/l *
S02 D 0.33	MD050	5.1 ug/l *
S03 D 0.33	MD051	100 ug/l *
S04 D 0.04	MD052	6.8 ug/l *

HVLS85

S_num/Depth	EPA Id	Perchlorate
S01 D 0.04	ML132	< 4 ug/l U*
S02 D 0.33	ML133	< 4 ug/l U*

HVLS44

S_num/Depth	EPA Id	Perchlorate
S01 D 0.04	ML053	3.1 ug/l J*
S02 D 0.33	ML054	1.2 ug/l J*
S04 D 0.04	ML055	5 ug/l *

HVLS86

S_num/Depth	EPA Id	Perchlorate
S01 D 0.04	ML134	< 4 ug/l U*

HVLS34

S_num/Depth	EPA Id	Perchlorate
S01 D 0.04	ML006	< 4 ug/l U*
S02 D 0.33	ML007	< 4 ug/l U*
S03 D 0.33	ML008	< 4 ug/l U*
S04 D 0.04	ML009	< 4 ug/l U*

HVLS87

S_num/Depth	EPA Id	Perchlorate
S01 D 0.04	ML135	7.7 ug/l *

HVLS88

S_num/Depth	EPA Id	Perchlorate
S01 D 0.04	ML136	3.9 ug/l J*

HVLS36

S_num/Depth	EPA Id	Perchlorate
S01 D 0.04	ML012	5.2 ug/l *
S02 D 0.33	ML013	2.3 ug/l J*
S04 D 0.04	ML014	2.9 ug/l J*

HVLS46

S_num/Depth	EPA Id	Perchlorate
S01 D 0.04	ML059	2.1 ug/l J*
S02 D 0.33	ML060	< 4 ug/l U*
S03 D 0.04	ML061	< 4 ug/l U*

HVLS37

S_num/Depth	EPA Id	Perchlorate
S01 D 0.04	ML015	5.9 ug/l *
S02 D 0.33	ML016	< 4 ug/l U*
S04 D 0.04	ML017	6.5 ug/l *

HVLS45

S_num/Depth	EPA Id	Perchlorate
S01 D 0.04	ML056	1.7 ug/l J*
S02 D 0.33	ML057	2.1 ug/l J*
S04 D 0.04	ML058	4 ug/l

HVLS47

S_num/Depth	EPA Id	Perchlorate
S01 D 0.04	ML062	< 4 ug/l U*
S02 D 0.33	ML063	< 4 ug/l U*
S04 D 0.04	ML086	< 4 ug/l U*

HVLS49

S_num/Depth	EPA Id	Perchlorate
S01 D 0.04	ML068	< 4 ug/l U*
S02 D 0.33	ML069	< 4 ug/l U*
S04 D 0.04	ML070	< 4 ug/l U*

HVLS48

S_num/Depth	EPA Id	Perchlorate
S01 D 0.04	ML064	< 4 ug/l U*
S02 D 0.33	ML065	< 4 ug/l U*
S03 D 0.33	ML066	< 4 ug/l U*
S04 D 0.04	ML067	< 4 ug/l U*

HVLS50

S_num/Depth	EPA Id	Perchlorate
S01 D 0.04	ML071	< 4 ug/l U*
S02 D 0.33	ML072	< 4 ug/l U*
S03 D 0.33	ML073	< 4 ug/l U*
S04 D 0.04	ML074	< 4 ug/l U*

HVLS51

S_num/Depth	EPA Id	Perchlorate
S01 D 0.04	ML075	< 4 ug/l U*
S02 D 0.33	ML076	< 4 ug/l U*
S04 D 0.04	ML078	< 4 ug/l U*
S99 D 0.50	MJ275	< 4 ug/l U*

HVLS52

S_num/Depth	EPA Id	Perchlorate
S01 D 0.04	ML079	< 4 ug/l U*
S02 D 0.33	ML080	< 4 ug/l U*
S04 D 0.04	ML081	< 8 ug/l U*

HVLS32

S_num/Depth	EPA Id	Perchlorate
S01 D 0.04	ML001	< 4 ug/l U*

HVLS53

S_num/Depth	EPA Id	Perchlorate
S01 D 0.04	ML082	< 4 ug/l U*
S02 D 0.33	ML083	< 4 ug/l U*
S03 D 0.33	ML084	< 4 ug/l U*
S04 D 0.04	ML085	< 4 ug/l U*

HVLS91 HVLS92 HVLS93 HVLS94 HVLS89 HVLS90 HVLX01 HVLX02 HVLX03 HVLX04 HVLX05 HVLX06 HVLX07 HVLX08 HVLX10 HVLX11 HVLX12 HVLX13 HVLX14 HVLX15 HVLX16

PERCHLORATE SOIL LEACHATE SAMPLING RESULTS (JUNE TO AUGUST 2003), SOUTHERN HAPPY VALLEY AREA

SANTA SUSANA FIELD LABORATORY

LEGEND

- RFI SOIL LEACHATE (6/30/03-7/22/03)
- SURFACE WATER FLOW (FROM SITES OF INTEREST FOR THIS REPORT)
- NPDES LOCATION
- SURFACE WATER DIVIDE (APPROXIMATE)
- FORMER INTERIM MEASURE EXCAVATION AREA

ug/l Micrograms Per Liter (ppb)

J Analyte Positively Identified; Associated Numerical Value Is Considered Estimated

U Analyte Not Detected; Associated Numerical Value Is The Detection Limit

* Data Validation in Progress; Preliminary Review Completed

Note:
1) Results depicted on map based on reviewed laboratory data available 8-12-03; final data validation in progress, but review sufficient for IM planning purposes.
2) Sample locations depicted in brown are pending reporting or analysis; data will be used to refine IM actions. Also, sampling in area continuing .

Concentration Ranges

<= 4 ug/l
<= 10 ug/l
<= 100 ug/l
> 100 ug/l

N

FEET

0 30 60 120 180 240

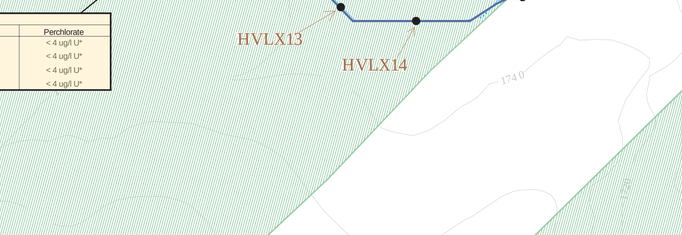
1 inch = 60 feet

Date: 08/16/03

File:/yap/rock/maps/figures/zn903002

MWH

F I G U R E
1
HVIM Amendment



S05,S06, etc to bedrock at 6" intervals

S99 are lateral composites comprised of several samples within active channel to 6"depths.

Santa Susana Field Laboratory

FIGURE 2
HVIM Amendment

MWH

PERCHLORATE ROCK CHIP SAMPLING RESULTS
(JUNE TO AUGUST 2003),
SOUTHERN HAPPY VALLEY AREA

LEGEND

▲	ROCK CHIP SAMPLE LOCATION
→	SURFACE WATER FLOW (FROM SITES OF INTEREST FOR THIS REPORT)
▭	FORMER INTERIM MEASURE EXCAVATION AREA
HVRC01	Sample Location ID
S01,S02,etc	Sample Number
D01,D02,etc	Duplicate Number
D##.#	Depth In Feet
R#####	Laboratory Reporting Code (EPA ID)
ug/kg ug/kg	Micrograms Per Kilogram (ppb) Micrograms Per Gram
J	Analyte Positively Identified; Associated Numerical Value Is Considered Estimated
U	Analyte Not Detected; Associated Numerical Value Is The Detection Limit
*	Data Validation in Progress; Preliminary Review Completed

Notes:
1. Results depicted on map based on reviewed laboratory data available 8-12-03; final data validation in progress, but review sufficient for IM planning purposes.
2. Sample locations depicted in brown are pending reporting or analysis; data will be used to refine IM actions. Also, sampling continuing in area.

Concentration Ranges
- <= 4 ug/l
- <=10 ug/l
- <= 100 ug/l
- > 100 ug/l

Base Map Legend

- Existing Building or Structure
- Removed Building or Structure
- Solvent Tanks, R Indicates Removed
- Petroleum Fuel/Oil Tanks, R Indicates Removed
- Hydrazine (MMH,UDMH,HZ) Tanks, R Indicates Removed
- Other Tanks, R Indicates Removed
- Awnings
- SWMU Boundary (if available)
- Monitoring Well
- Administrative Area Boundary
- Ground Elevation Contours
- A/C Curbing
- Dirt Road
- Possible Ponds (approx. location)
- Ponds
- Creeks
- Shale Units
- Faults
- Faults (Approximate)
- Estimated Contact Line

Date: 08/16/03

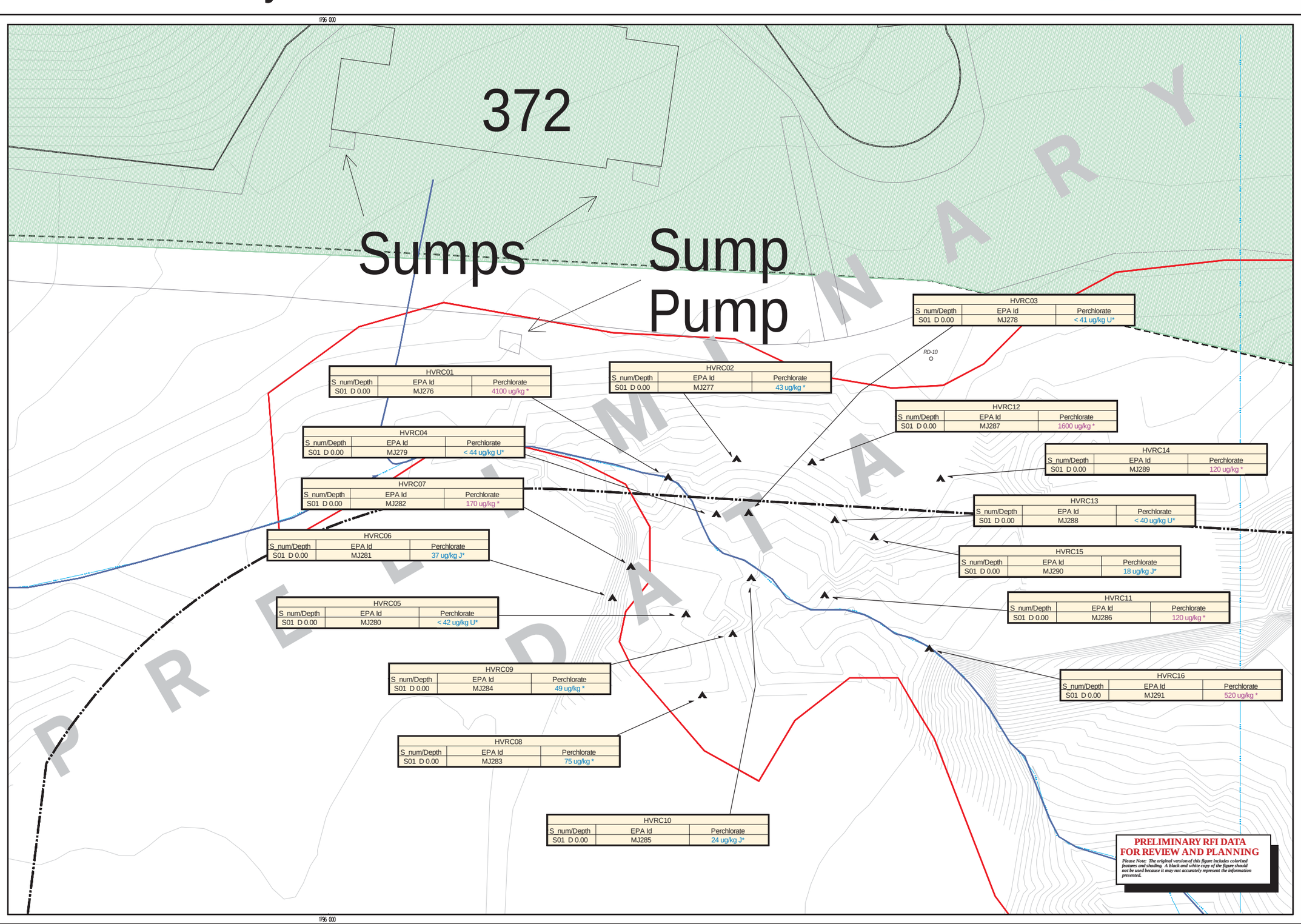
File:/yap/rock/maps/figures/zn903000, Task 101

N

0 20
FEET

1 inch = 20 feet

Key Map



HVRC01		
S_num/Depth	EPA Id	Perchlorate
S01 D 0.00	MJ276	4100 ug/kg *

HVRC02		
S_num/Depth	EPA Id	Perchlorate
S01 D 0.00	MJ277	43 ug/kg *

HVRC03		
S_num/Depth	EPA Id	Perchlorate
S01 D 0.00	MJ278	< 41 ug/kg U*

HVRC04		
S_num/Depth	EPA Id	Perchlorate
S01 D 0.00	MJ279	< 44 ug/kg U*

HVRC05		
S_num/Depth	EPA Id	Perchlorate
S01 D 0.00	MJ280	< 42 ug/kg U*

HVRC06		
S_num/Depth	EPA Id	Perchlorate
S01 D 0.00	MJ281	37 ug/kg J*

HVRC07		
S_num/Depth	EPA Id	Perchlorate
S01 D 0.00	MJ282	170 ug/kg *

HVRC08		
S_num/Depth	EPA Id	Perchlorate
S01 D 0.00	MJ283	75 ug/kg *

HVRC09		
S_num/Depth	EPA Id	Perchlorate
S01 D 0.00	MJ284	49 ug/kg *

HVRC10		
S_num/Depth	EPA Id	Perchlorate
S01 D 0.00	MJ285	24 ug/kg J*

HVRC11		
S_num/Depth	EPA Id	Perchlorate
S01 D 0.00	MJ286	120 ug/kg *

HVRC12		
S_num/Depth	EPA Id	Perchlorate
S01 D 0.00	MJ287	1600 ug/kg *

HVRC13		
S_num/Depth	EPA Id	Perchlorate
S01 D 0.00	MJ288	< 40 ug/kg U*

HVRC14		
S_num/Depth	EPA Id	Perchlorate
S01 D 0.00	MJ289	120 ug/kg *

HVRC15		
S_num/Depth	EPA Id	Perchlorate
S01 D 0.00	MJ290	18 ug/kg J*

HVRC16		
S_num/Depth	EPA Id	Perchlorate
S01 D 0.00	MJ291	520 ug/kg *

Santa Susana Field Laboratory

FIGURE 3
HVIM Amendment

MWH

PERCHLORATE SOIL LEACHATE SAMPLING RESULTS NEAR FORMER BUILDING FOUNDATIONS (JUNE TO AUGUST 2003), BUILDING 359 AND HAPPY VALLEY AREAS

LEGEND

- RFI SOIL LEACHATE (6/30/03-7/22/03)
- RFI LATERAL COMPOSITE SOIL LEACHATE SAMPLE AREA
- SURFACE WATER FLOW (FROM SITES OF INTEREST FOR THIS REPORT)
- SURFACE WATER DIVIDE (APPROXIMATE)
- FORMER INTERIM MEASURE EXCAVATION AREA
- BSLS16 — Sample Location ID (Ogden ID)
- S01,S02,etc — Sample Number
- D01,D02,etc — Duplicate Number
- D##.# — Depth In Feet
- R#### — Laboratory Reporting Code (EPA ID)
- ug/l — Micrograms Per Liter (ppb)
- J — Analyte Positively Identified; Associated Numerical Value Is Considered Estimated
- U — Analyte Not Detected; Associated Numerical Value Is The Detection Limit
- * — Data Validation in Progress; Preliminary Review Completed

Notes:
1. Results depicted on map based on reviewed laboratory data available 8-12-03; final data validation in progress, but review sufficient for IM planning purposes.
2. Sample locations depicted in brown are pending reporting or analysis; data will be used to refine IM actions. Also, sampling continuing in area.

Concentration Ranges

<= 4 ug/l
<= 10 ug/l
<= 100 ug/l
> 100 ug/l

Base Map Legend

- Existing Building or Structure
- Removed Building or Structure
- Solvent Tanks, R Indicates Removed
- Petroleum Fuel/Oil Tanks, R Indicates Removed
- Hydrazine (MMH,UDMH,HZ) Tanks, R Indicates Removed
- Other Tanks, R Indicates Removed
- Awnings
- SWMU Boundary (if available)
- HAR-2 Monitoring Well
- Administrative Area Boundary
- Ground Elevation Contours
- A/C Curbing
- Dirt Road
- Possible Ponds (approx. location)
- Ponds
- Creeks
- Shale Units
- Faults
- Faults (Approximate)
- Estimated Contact Line

Date: 08/16/03

File:/yap/rock/maps/figures/zr602999, Task 101

0 180
FEET
1 inch = 180 feet

Key Map

BSLS16		
S_num/Depth	EPA Id	Perchlorate
S01 D 0.04	ML028	< 4 ug/l U*
S02 D 0.33	ML029	25 ug/l *
S99 D 0.50	MJ269	< 4 ug/l U*

BSLS18		
S_num/Depth	EPA Id	Perchlorate
S01 D 0.04	ML033	33 ug/l *
S02 D 0.33	ML034	6.9 ug/l *
S03 D 0.33	ML035	< 4 ug/l U*
S04 D 0.04	ML036	< 4 ug/l U*

BSLS17		
S_num/Depth	EPA Id	Perchlorate
S01 D 0.04	ML030	< 4 ug/l U*
S02 D 0.33	ML031	< 4 ug/l U*
S04 D 0.04	ML032	< 4 ug/l U*

S04 = 0 - 0.5 "
S99 = 0 - 6 " (see below)
S01 = 0 - 0.5 "
S03 = 0 - 4 "
S02 = 0.5 - 4 "
S05,S06, etc to bedrock at 6" intervals

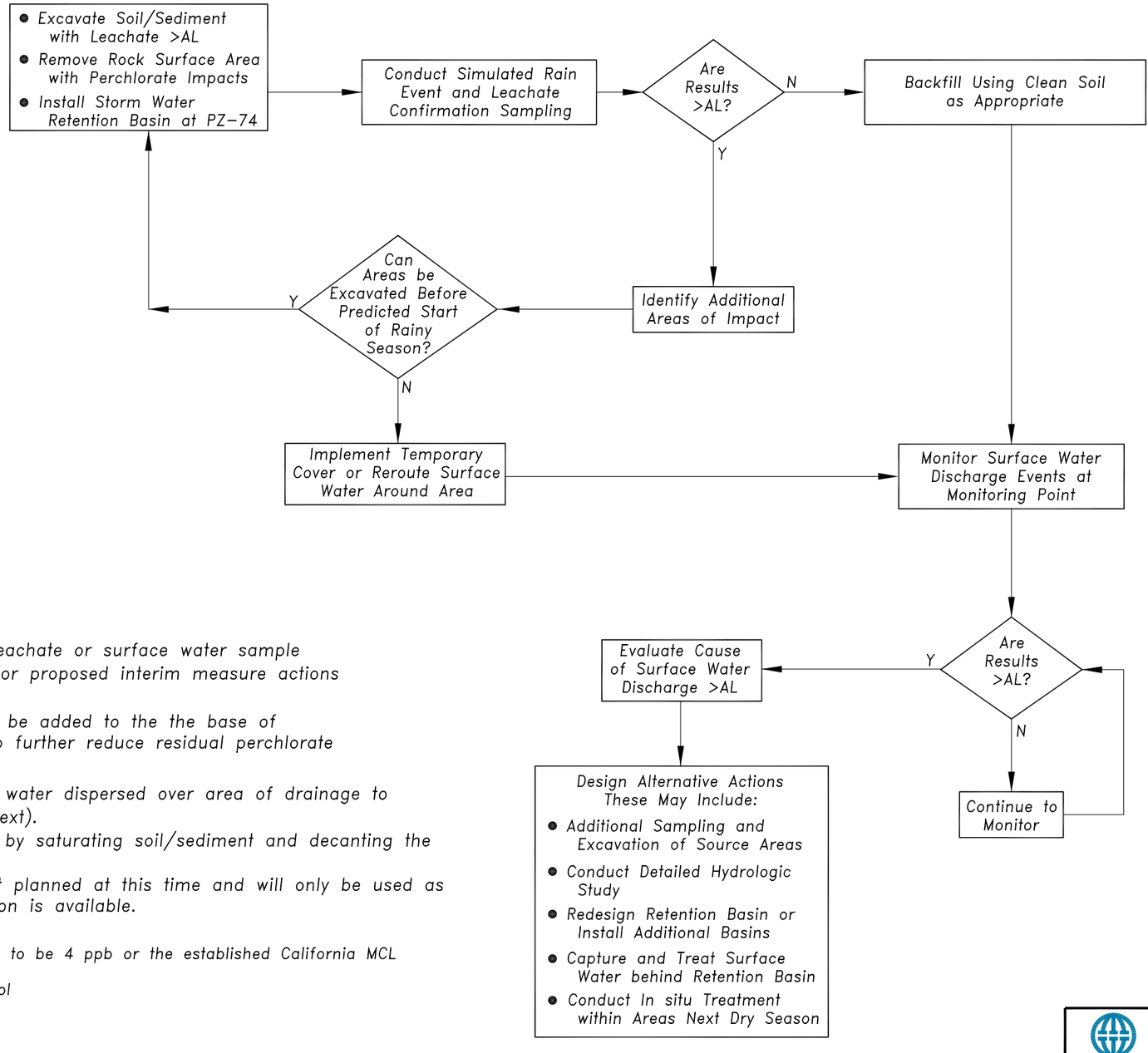
S99 are lateral composites comprised of several samples within active channel to 6"depths.

HVLS60		
S_num/Depth	EPA Id	Perchlorate
S01 D 0.50	ML128	3.6 ug/l J*

PRELIMINARY RFI DATA FOR REVIEW AND PLANNING

Please Note: The original version of this figure includes colorand features and shading. A black and white copy of the figure should not be used because it may not accurately represent the information presented.

Building 359
Happy Valley
APTF
IEL
Area I Road
Research Road
Former Test Bay 4
Former Test Bay 3
Test Bay 1
Test Bay 2
Storm Water Culvert
Storm Water Discharge Culvert
Discharge Pipeline from Storage Area
Oxidizer Preparation Bldg.
Oxidizer Storage and Loading Dock
Oxidizer Storage
Igniter Storage
Motor Test Area
Water Pipeline
Former Energetic Materials Storage
Discharge Pipeline from B372 Sumps
Propellant Press Bldg
Propellant Lab
Gun Range Backstop
Former Control Center
Gun Mount Area
Sumps
Sump Pump
Concrete Swale
1795 000
1796 000
1797 000
267 000
268 000



Notes:

1. The AL has been used as the soil leachate or surface water sample (artificial or natural) 'trigger level' for proposed interim measure actions within the Happy Valley drainage.
2. A biotreatment soil amendment may be added to the the base of the excavaton as a polishing step to further reduce residual perchlorate that may be present (see text).
3. Simulated rain event = fire hydrant water dispersed over area of drainage to create artificial surface water (see text).
4. Leachate = water samples collected by saturating soil/sediment and decanting the liquid (see text).
5. Permanent sealing of bedrock is not planned at this time and will only be used as an interim measure if no other option is available.

AL = Surface Water Action Level, considered to be 4 ppb or the established California MCL
COPC = Chemical of Potential Concern
DTSC = Department of Toxic Substances Control
MCL = Maximum Contaminant Level

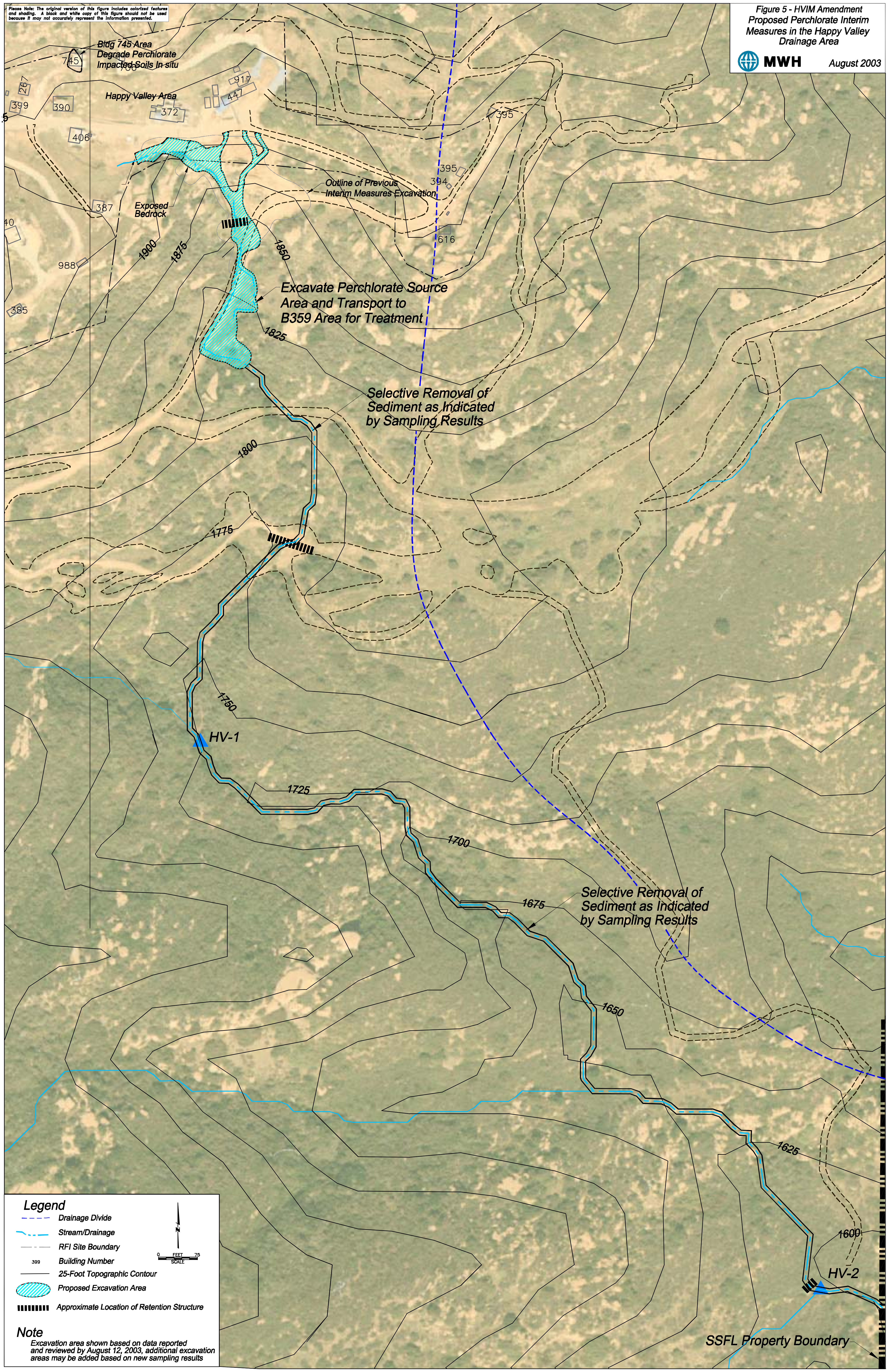
MWH

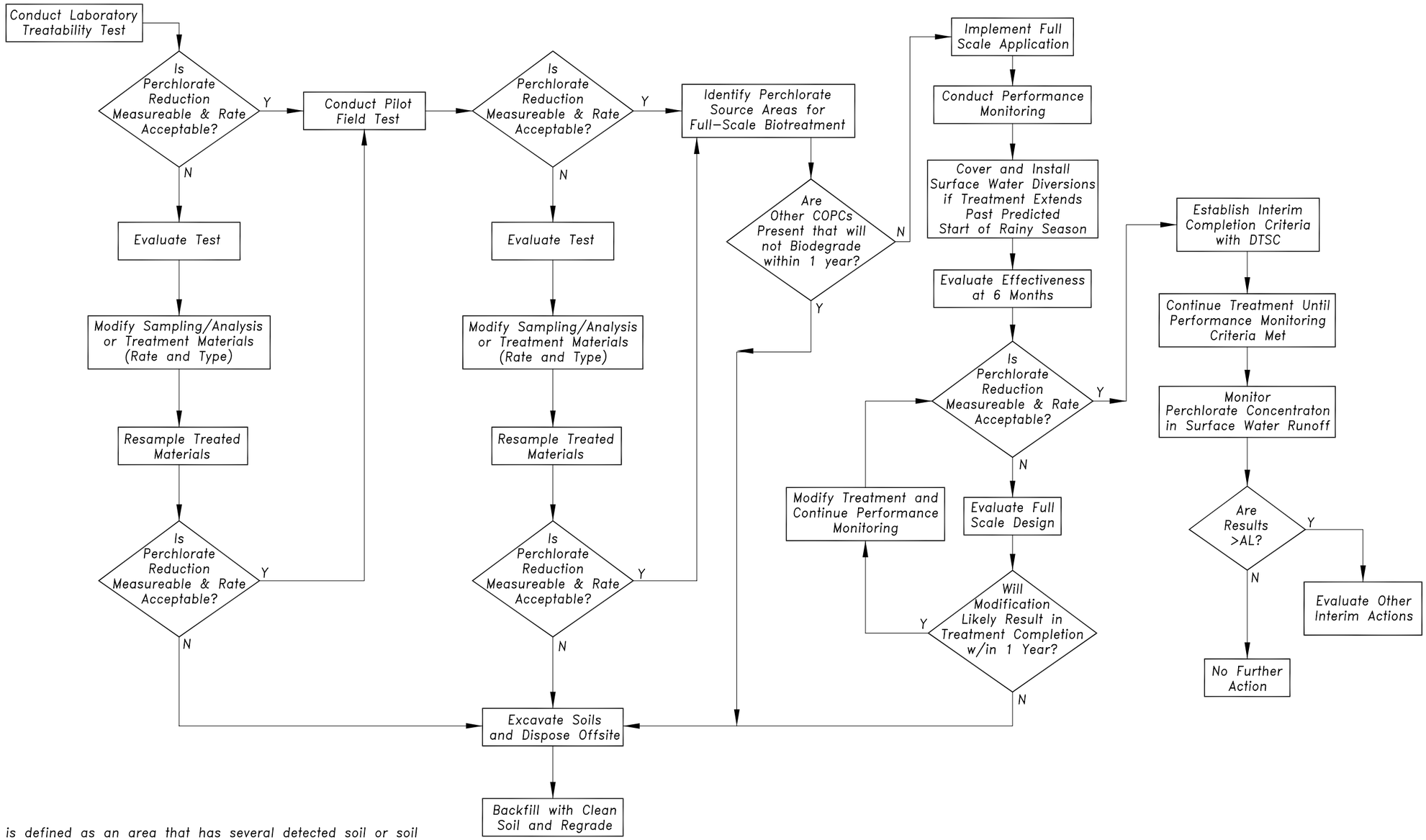
SANTA SUSANA FIELD LABORATORY
VENTURA COUNTY, CALIFORNIA

DECISION TREE FOR PERCHLORATE INTERIM MEASURES IN THE HAPPY VALLEY DRAINAGE

FIGURE 4 – HVIM Amendment

JOB No. ___ FILE No. ___ INDSVR\INDUSTRIAL\CAD MLUEBKE\BOEING\SANTA SUSANA\HAPPY VALLEY FLOW CHART 8 12 03


Please Note: The original version of this figure includes colorized features and shading. A black and white copy of this figure should not be used because it may not accurately represent the information presented.
Figure 5 - HVIM Amendment
Proposed Perchlorate Interim
Measures in the Happy Valley
Drainage Area
MWH
August 2003
Bldg 745 Area
Degrade Perchlorate
Impacted Soils In situ
Happy Valley Area
745
706
917
447
267
399
390
372
406
395
395
394
387
616
988
385
40
Exposed
Bedrock
Outline of Previous
Interim Measures Excavation
1900
1875
1850
1825
1800
1775
1750
1725
1700
1675
1650
1625
1600
Excavate Perchlorate Source
Area and Transport to
B359 Area for Treatment
Selective Removal of
Sediment as Indicated
by Sampling Results
HV-1
Selective Removal of
Sediment as Indicated
by Sampling Results
HV-2
SSFL Property Boundary
Legend
Drainage Divide
Stream/Drainage
RFI Site Boundary
399
Building Number
25-Foot Topographic Contour
Proposed Excavation Area
Approximate Location of Retention Structure
N
0
FEET
75
SCALE
Note
Excavation area shown based on data reported
and reviewed by August 12, 2003, additional excavation
areas may be added based on new sampling results



Notes:

1. *A "perchlorate source area" is defined as an area that has several detected soil or soil leachate concentrations that appear to contribute to surface water runoff > the AL.*
2. *Measurable perchlorate reduction will be determined based on soil matrix and soil leachate sample laboratory results.*
3. *Treatment rate will be deemed acceptable if perchlorate concentrations can be reduced within a period of about 1-year so that there is not a continuing contribution to surface water runoff greater than the AL.*

AL = *Surface Water Action Level, considered to be 4 ppb or the established California MCL*
COPC = *Chemical of Potential Concern*
DTSC = *Department of Toxic Substances Control*
MCL = *Maximum Contaminant Level*

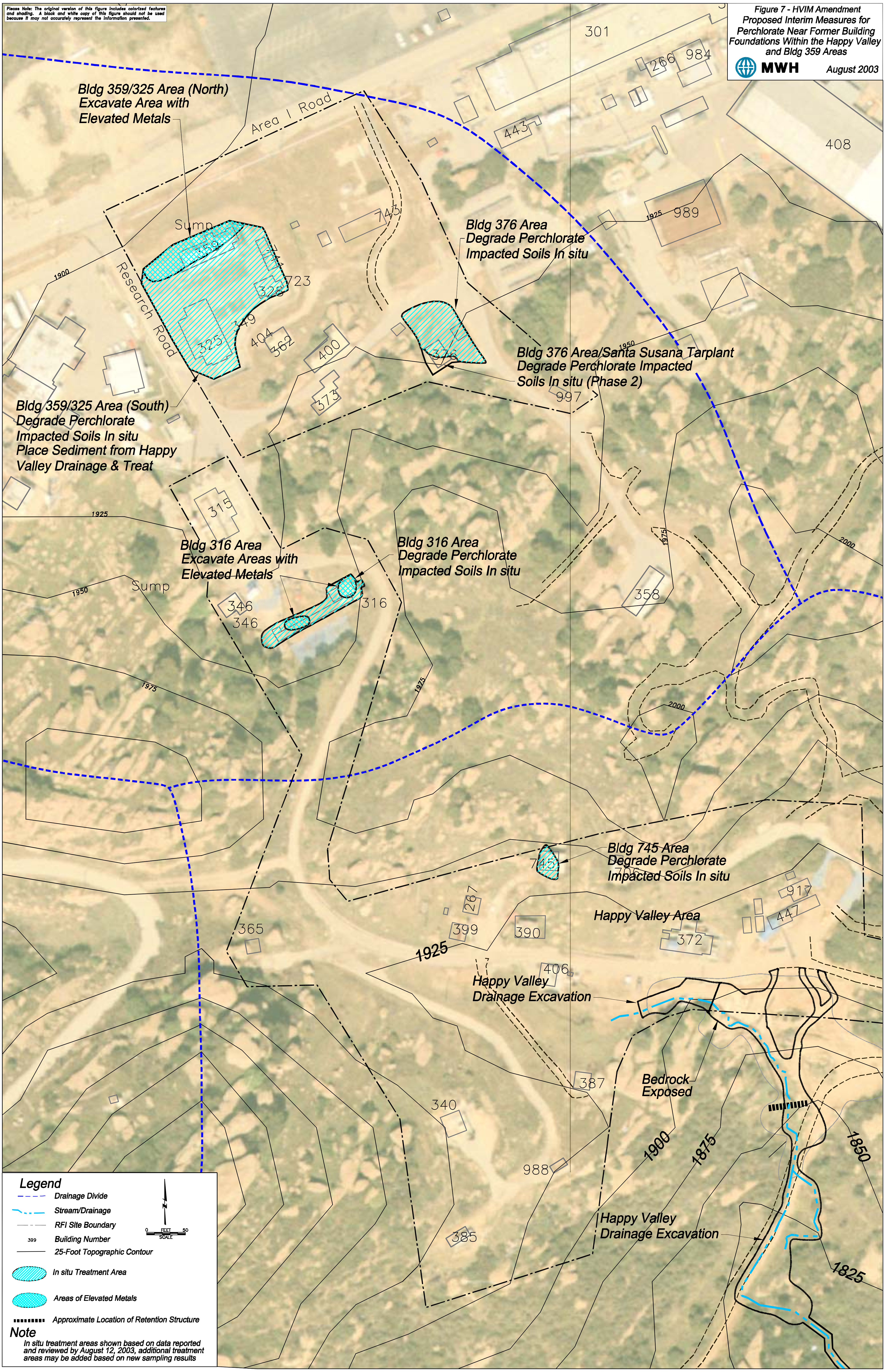
MWH

SANTA SUSANA FIELD LABORATORY
VENTURA COUNTY, CALIFORNIA

DECISION TREE FOR PERCHLORATE INTERIM MEASURES NEAR FORMER BUILDING FOUNDATIONS IN THE HAPPY VALLEY & BLDG 359 AREAS

FIGURE 6 – HVIM Amendment

JOB No. -- FILE No. INDSVR\INDUSTRIAL\CAD MLUEBKE\BOEING\SANTA SUSANA\HAPPY VALLEY FLOW CHART 7 30 03



Please Note: The original version of this figure includes colorized features and shading. A black and white copy of this figure should not be used because it may not accurately represent the information presented.
Figure 7 - HVIM Amendment
Proposed Interim Measures for Perchlorate Near Former Building Foundations Within the Happy Valley and Bldg 359 Areas
MWH
August 2003
Bldg 359/325 Area (North) Excavate Area with Elevated Metals
Area I Road
Research Road
Sump
Bldg 376 Area Degrade Perchlorate Impacted Soils In situ
Bldg 376 Area/Santa Susana Tarplant Degrade Perchlorate Impacted Soils In situ (Phase 2)
Bldg 359/325 Area (South) Degrade Perchlorate Impacted Soils In situ Place Sediment from Happy Valley Drainage & Treat
Bldg 316 Area Excavate Areas with Elevated Metals
Bldg 316 Area Degrade Perchlorate Impacted Soils In situ
Bldg 745 Area Degrade Perchlorate Impacted Soils In situ
Happy Valley Area
Happy Valley Drainage Excavation
Bedrock Exposed
Happy Valley Drainage Excavation
301
266
984
408
443
989
743
359
723
328
325
349
404
362
400
376
373
997
315
346
346
316
358
745
706
917
447
267
399
390
372
406
365
387
340
988
385
1900
1925
1950
1975
2000
1925
1900
1875
1850
1825
Legend
Drainage Divide
Stream/Drainage
RFI Site Boundary
399 Building Number
25-Foot Topographic Contour
In situ Treatment Area
Areas of Elevated Metals
Approximate Location of Retention Structure
0 FEET 50
SCALE
Note
In situ treatment areas shown based on data reported and reviewed by August 12, 2003, additional treatment areas may be added based on new sampling results

Department of Toxic Substances Control

Edwin F. Lowry, Director
8800 Cal Center Drive
Sacramento, California 95826-3200

Winston H. Hickox
Agency Secretary
California Environmental
Protection Agency

Gray Davis
Governor

August 1, 2003

Mr. Art Lenox
Environmental Remediation
The Boeing Company
6633 Canoga Avenue
P.O. Box 7922
Canoga Park, California 91309-7922

Dear Mr. Lenox:

This letter is to confirm your recent communication with Mr. Ray Leclerc of this office, that The Boeing Company will be submitting no later than August 18, 2003, a response to our July 28, 2003 comments regarding your work plan entitled, "Happy Valley Interim Measures Work Plan Addendum, Happy Valley and Building 359, Areas of Concern, Santa Susana Field Laboratory", dated June 16, 2003.

I understand that The Boeing Company may email some responses before this date to expedite our review. I suggest you include the Los Angeles Regional Water Quality Control Board on these earlier submittals.

We look forward to your submittals. If you have any questions, please contact Mr. Leclerc at (916) 255-3582.

Sincerely,

James M. Pappas

James M. Pappas, P.E., Chief
Northern California Permitting and Corrective Action Branch

cc: See next page.

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The energy challenge facing California is real. Every Californian needs to take immediate action to reduce energy consumption. For a list of simple ways you can reduce demand and cut your energy costs, see our Web-site at www.dtsc.ca.gov.

002154 RC

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cc: Mr. Dave Bacharowski
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Los Angeles, California 90013

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Winston H. Hickox
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California Environmental
Protection Agency

Gray Davis
Governor

July 28, 2003

Mr. Steve Lafflam, Division Director
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HAPPY VALLEY INTERIM MEASURES WORK PLAN ADDENDUM, SANTA SUSANA FIELD LABORATORY, EPA ID CAD 093365435

Dear Mr. Lafflam:

The Department of Toxic Substances Control (DTSC) has completed the review of the *Happy Valley Interim Measures Work Plan Addendum, Happy Valley and Building 359 Areas of Concern, Santa Susana Field Laboratory*, dated June 16, 2003, referred to as the Workplan. Below you will find our comments:

1. The Workplan needs to include a more detailed description of past practices and specific operations associated with portions of buildings and other areas of investigation. This background information is vital in determining the adequacy of the sampling regime. This will likely require more detailed figures for individual buildings and areas of interest.

2. The Workplan needs to describe the rationale behind the sampling locations at the Building 359 area and within the Happy Valley Area. The discussion should begin with a background and rationale describing why some areas were sampled while others were not. In addition, the type of sampling chosen, such as random, biased, or grid sampling should be discussed. This should include criteria for each sample collected and sub-area that is under investigation.

3. The Workplan needs to have a conclusion section where the existing information is summarized and hypotheses addressing the occurrence, fate and transport of perchlorate are proposed. While data gaps will remain, it is important to propose hypotheses that explain the results found at the site in order to identify data gaps, plan for future activities, and develop consensus.

4. The Workplan needs to identify all specific measures that will be taken to prevent surface water discharges contaminated with perchlorate during the wet season of 2003/04 in areas where residual perchlorate will remain in place.

5. All areas where insitu treatment or soil removal is proposed must be more clearly defined. Areas of concern need to be characterized laterally and to bedrock. To the extent possible, shallow bedrock should be sampled in areas with significant contamination. If additional areas are to be added in the future, as additional data is collected, the specific conditions and criteria for inclusion need to be specified.

6. The purpose of the Workplan is to support an interim measure proposed for the Fall and Winter of 2003. While the data collected will clearly add to site understanding, additional data will likely be needed to support the final RFI and final remedy.

7. Limits of detection need to be discussed in the Workplan. The discussion should include the required Detection Limits (DLs) for each media and samples that did not meet the DLs and explanation; samples that do not may require resampling.

8. The use of soil leachate analysis is likely to be an effective tool in identifying perchlorate in the soil matrix. A discussion including a rationale for this innovative procedure should be provided in the interim measures report.

9. A map is needed that shows areas of contamination by color code, going from the lowest detections up to the highest levels – similar to a groundwater plume map, but for soils.

10. Specific case studies demonstrating insitu biodegradation of perchlorate in soil must be provided. There needs to be a sufficient number compelling field studies or successful case studies to support the use bioremediation at the Santa Susana Facility.

11. Contaminants other than perchlorate, such as solvents, metals, and MDMA, are not discussed in the areas where activities are proposed. The potential for other contaminants in soil and surface water and their impact on this project should be discussed.

12. The Workplan will need to be revised to divide the proposed field work into two phases: phase one will avoid the special status plant, Santa Susana Tar Plant; the second phase must address the mitigation measures for disturbance of special status plant species.

In addition, you will find enclosed the California Regional Water Quality Control Board, Los Angeles Region, comments on the Workplan dated July 15, 2003. Boeing will need to address both sets of comments before DTSC can approve the Workplan.

If you have any questions with regard to this issue, please call Mr. Ray Leclerc, at (916) 255-3582.

Sincerely,

James M. Pappas, P.E., Chief
Northern California Permitting and Corrective Action Branch

cc:

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California Regional Water Quality Control Board

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Phone (213) 576-6600 FAX (213) 576-6640 - Internet Address: http://www.swrcb.ca.gov/rwqcb4

July 15, 2003

Mr. James M. Pappas, P.E., Chief
Sacramento Permitting and Corrective Action Branch
Hazardous Waste Management Program
Department of Toxic Substances Control
8800 Cal Center Drive
Sacramento, CA 95826-3200

HAPPY VALLEY INTERIM MEASURES WORK PLAN ADDENDUM, HAPPY VALLEY AND BUILDING 359 AREAS OF CONCERN – BOEING, SANTA SUSANA FIELD LABORATORY, VENTURA COUNTY, CALIFORNIA (CA 0001309)

Dear Mr. Pappas:

Los Angeles Regional Water Quality Control Board (Regional Board) staff have reviewed the June 2003, *Happy Valley Interim Measures Work Plan Addendum, Happy Valley and Building 359 Areas of Concern* (Workplan), and have the following comments:

1. Boeing must provide case histories on the use of cow manure for the remediation of perchlorate in situations similar to those present at the Santa Susana Field Laboratory;

2. Boeing must be made aware that site-specific, individual Waste Discharge Requirements (WDRs) will be required by the Regional Board for the aboveground bioremediation of any perchlorate (or other constituent) contaminated soil. Boeing must initiate the WDR process by immediately submitting a Report of Waste Discharge to operate a land treatment unit;

3. Although the use of shot-crete or epoxy sealant is acceptable for sealing contaminated bedrock, this will create an extended period of quality control, inspection and maintenance;

4. Boeing must provide details of how they propose to conduct the simulated rain event, flooding, and runoff, and capture study for the evaluation of perchlorate transport in surface water following source area excavation;

5. Boeing must install proper drainage controls during excavation to prevent contaminated runoff from entering surface watercourses, such as ½-round corrugated metal pipe, berms, or sandbags. The drainage controls must be designed for a 25-year, 24-hour duration storm, at minimum; and

6. Please require that Boeing use clean soil as backfill in all excavations. "Clean soil" is defined as remediated soil containing contaminants which are at, or below, the Regional Board's May 1996 *Interim Site Assessment and Cleanup Guidebook* cleanup goals to protect groundwater quality. The top two feet of backfill must be uncontaminated, imported soils in order to prevent surface water contamination.

The Regional Board considers this cleanup project to be a high priority and will provide any technical support necessary in a timely manner. We would also like to emphasize the necessity and importance of completing this project prior to the next rainy season. The discharge of perchlorate in surface water runoff from the Building 359 area during future rain events must cease. We also request that any other agencies involved with approving this cleanup project also identify this cleanup project as a high priority and support the efforts of the DTSC in implementing the project in a timely manner.

We appreciate the opportunity to comment on the Workplan. Should you have any questions, please contact Mr. David Bacharowski at (213) 576-6607 or Mr. Peter Raftery at (213) 576-6724.

Sincerely,

Dennis A. Dickerson
Executive Officer

cc: Regional Board Members
Michael Lauffer, Office of the Chief Counsel, State Water Resources Control Board
The Honorable Steve Bennett, Ventura County Board of Supervisors
The Honorable John Flynn, Ventura County Board of Supervisors
The Honorable Kathy Long, Ventura County Board of Supervisors
The Honorable Judy Mikels, Ventura County Board of Supervisors
The Honorable Frank Schillo, Ventura County Board of Supervisors
Mr. Gerard Abrams, DTSC Sacramento
Dr. Lowell Preston, Ventura County Public Works Agency
Mr. Aaron Allen, Army Corps of Engineers Ventura County Field Office
Ms. Natasha Lohmus, California Department of Fish and Game
Ms. Mary Meyer, California Department of Fish and Game-South Coast Region
Mrs. Sharon Rubalcava, Weston Benshoof Rochefort Rubalcava MacCuish LLP
Mrs. Mary Weisbrock, Save Open Spaces
Mr. Daniel Hirsch, Committee to Bridge the Gap

California Regional Water Quality Control Board

Los Angeles Region

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July 15, 2003

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Sacramento, CA 95826-3200

HAPPY VALLEY INTERIM MEASURES WORK PLAN ADDENDUM, HAPPY VALLEY AND BUILDING 359 AREAS OF CONCERN – BOEING, SANTA SUSANA FIELD LABORATORY, VENTURA COUNTY, CALIFORNIA (CA 0001309)

Dear Mr. Pappas:

Los Angeles Regional Water Quality Control Board (Regional Board) staff have reviewed the June 2003, *Happy Valley Interim Measures Work Plan Addendum, Happy Valley and Building 359 Areas of Concern* (Workplan), and have the following comments:

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3. Although the use of shot-crete or epoxy sealant is acceptable for sealing contaminated bedrock, this will create an extended period of quality control, inspection and maintenance;

4. Boeing must provide details of how they propose to conduct the simulated rain event, flooding, and runoff, and capture study for the evaluation of perchlorate transport in surface water following source area excavation;

5. Boeing must install proper drainage controls during excavation to prevent contaminated runoff from entering surface watercourses, such as ½-round corrugated metal pipe, berms, or sandbags. The drainage controls must be designed for a 25-year, 24-hour duration storm, at minimum; and

6. Please require that Boeing use clean soil as backfill in all excavations. "Clean soil" is defined as remediated soil containing contaminants which are at, or below, the Regional Board's May 1996 *Interim Site Assessment and Cleanup Guidebook* cleanup goals to protect groundwater quality. The top two feet of backfill must be uncontaminated, imported soils in order to prevent surface water contamination.

The Regional Board considers this cleanup project to be a high priority and will provide any technical support necessary in a timely manner. We would also like to emphasize the necessity and importance of completing this project prior to the next rainy season. The discharge of perchlorate in surface water runoff from the Building 359 area during future rain events must cease. We also request that any other agencies involved with approving this cleanup project also identify this cleanup project as a high priority and support the efforts of the DTSC in implementing the project in a timely manner.

We appreciate the opportunity to comment on the Workplan. Should you have any questions, please contact Mr. David Bacharowski at (213) 576-6607 or Mr. Peter Raftery at (213) 576-6724.

Sincerely,

Dennis A. Dickerson
Executive Officer

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The Honorable Judy Mikels, Ventura County Board of Supervisors
The Honorable Frank Schillo, Ventura County Board of Supervisors
Mr. Gerard Abrams, DTSC Sacramento
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Mr. Aaron Allen, Army Corps of Engineers Ventura County Field Office
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Ms. Mary Meyer, California Department of Fish and Game-South Coast Region
Mrs. Sharon Rubalcava, Weston Benshoof Rochefort Rubalcava MacCuish LLP
Mrs. Mary Weisbrock, Save Open Spaces
Mr. Daniel Hirsch, Committee to Bridge the Gap

Appendix A
Happy Valley Interim Measures Work Plan Addendum Amendment
Santa Susana Field Laboratory

Response to Comments in DTSC letter dated July 28, 2003
Prepared by MWH for The Boeing Company

DTSC Comment:	Response:
1. The Workplan needs to include a more detailed description of past practices and specific operations associated with portions of buildings and other areas of investigation. This background information is vital in determining the adequacy of the sampling regime. This will likely require more detailed figures for individual buildings and areas of interest.	1. Section 2.0 and Tables 1 and 2 of the HVIM Amendment include discussions and summaries specific to buildings and areas of investigation, including historical use and operations.
2. The Workplan needs to describe the rationale behind the sampling locations at the Building 359 area and within the Happy Valley Area. The discussion should begin with a background and rationale describing why some areas were sampled while others were not. In addition, the type of sampling chosen, such as random, biased, or grid sampling should be discussed. This should include criteria for each sample collected and sub-area that is under investigation.	2. Rationale and sample locations are addressed in Section 2.0 and Tables 1 and 2 of the HVIM Amendment. Hundreds of samples have been collected from various media, e.g., soil, sediment, bedrock, water, in the Building 359 and Happy Valley Areas. Biased sample locations were based on historic operations. Ongoing sampling has further targeted those locations that indicated perchlorate or other chemicals of potential concern were present.
3. The Workplan needs to have a conclusion section where the existing information is summarized and hypotheses addressing the occurrence, fate and transport of perchlorate are proposed. While data gaps will remain, it is important to propose hypotheses that explain the results found at the site in order to identify data gaps, plan for future activities, and develop consensus.	3. Subsections 2.3 and 2.4, Tables 1 and 2, and Figures 1, 2, and 3 provide summary information regarding perchlorate occurrence and fate.

Appendix A
Happy Valley Interim Measures Work Plan Addendum Amendment
Santa Susana Field Laboratory

Response to Comments in DTSC letter dated July 28, 2003
Prepared by MWH for The Boeing Company

DTSC Comment:	Response:
4. The Workplan needs to identify all specific measures that will be taken to prevent surface water discharges contaminated with perchlorate during the wet season of 2003/04 in areas where residual perchlorate will remain in place.	4. The HVIM Amendment was written for the purpose of further detailing the actions that will be implemented to achieve water quality objectives for perchlorate. Areas where treatment will not be complete by the predicted start of the 2003 rainy season will be tarped to protect against further perchlorate migration to surface water. Please see Sections 3 and 4 of the HVIM Work Plan Amendment.
5. All areas where *in situ* treatment or soil removal is proposed must be more clearly defined. Areas of concern need to be characterized laterally and to bedrock. To the extent possible, shallow bedrock should be sampled in areas with significant contamination. If additional areas are to be added in the future, as additional data is collected, the specific conditions and criteria for inclusion need to be specified.	5. Continued sampling has resulted in greater characterization of the Building 359 and Happy Valley Areas. Soil, sediment, and bedrock samples have been collected, and the data summarized on Figures 1, 2, and 3. Sampling is ongoing to define the limits of the proposed actions. Proposed excavation and *in situ* treatment areas are depicted on Figures 5 and 7. Criteria for additional actions are provided in Tables 3 and 4.
6. The purpose of the Workplan is to support an interim measure proposed for the Fall and Winter of 2003. While the data collected will clearly add to site understanding, additional data will likely be needed to support the final RFI and final remedy.	6. The HVIM Amendment is intended to present interim measures that will achieve proposed water quality objectives for perchlorate. Additional data may be needed to support a final remedy; however, based on the interim measures being taken, additional mitigation may not be necessary if the interim measures achieve the stated objectives.

Appendix A
Happy Valley Interim Measures Work Plan Addendum Amendment
Santa Susana Field Laboratory

Response to Comments in DTSC letter dated July 28, 2003
Prepared by MWH for The Boeing Company

DTSC Comment:	Response:
7. Limits of detection need to be discussed in the Workplan. The discussion should include the required Detection Limits (DLs) for each media and samples that did not meet the DLs and explanation; samples that do not may require resampling.	7. Detection limits and analytical procedures are discussed in Subsection 2.2.3 of the HVIM Amendment. As explained in this subsection, additional measures have been implemented to achieve the lowest possible detection limits. Data review is ongoing.
8. The use of soil leachate analysis is likely to be an effective tool in identifying perchlorate in the soil matrix. A discussion including a rationale for this innovative procedure should be provided in the interim measures report.	8. Subsection 2.2.2 of the HVIM Amendment discusses the soil/sediment leachate procedure and its application in characterizing perchlorate occurrence. The rationale for using this procedure is also included.
9. A map is needed that shows areas of contamination by color code, going from the lowest detections up to the highest levels – similar to a groundwater plume map, but for soils.	9. Based on the somewhat heterogeneous and varying occurrence of perchlorate in soil, sediment, sediment leachate, and bedrock, a typical "plume map" cannot be developed. However, Figures 1, 2, and 3 depict different concentrations of detected perchlorate in various colors.
10. Specific case studies demonstrating *in situ* biodegradation of perchlorate in soil must be provided. There needs to be a sufficient number compelling field studies or successful case studies to support the use of bioremediation at the Santa Susana Facility.	10. Boeing is conducting bench-scale, and potentially field-scale studies to better establish what compound will be used to aid in degrading perchlorate. Several case studies, supporting the degradation of perchlorate, are included in the HVIM Amendment as Appendix B.

Appendix A
Happy Valley Interim Measures Work Plan Addendum Amendment
Santa Susana Field Laboratory

Response to Comments in DTSC letter dated July 28, 2003
Prepared by MWH for The Boeing Company

DTSC Comment:	Response:
11. Contaminants other than perchlorate, such as solvents, metals, and MDMA, are not discussed in the areas where activities are proposed. The potential for other contaminants in soil and surface water and their impact on this project should be discussed.	11. Samples have been analyzed for constituents other than perchlorate. Section 4.0 discusses COPCs detected and Figure 7 identifies their locations in areas identified for perchlorate *in situ* treatment. COPCs that occur in perchlorate-impacted areas are being addressed in the HVIM Amendment.
12. The Workplan will need to be revised to divide the proposed field work into two phases: phase one will avoid the special status plant, Santa Susana Tar Plant; the second phase must address the mitigation measures for disturbance of special status plant species.	12. The HVIM Amendment specifically addresses those areas where Santa Susana Tarplant can be avoided. As these areas will be mitigated prior to the winter 2003/2004 rainy season. In areas where Santa Susana Tarplant cannot be avoided, special permitting will be required. Phase II of the HVIM will be conducted after the special permit is obtained (the permit may require up to 9 months to obtain). Section 1, Page 3 addresses the phasing of work.

Appendix A

Happy Valley Interim Measures Work Plan Addendum Amendment
Santa Susana Field Laboratory

Response to Comments in RWQCB Letter dated July 15, 2003
Prepared by MWH for The Boeing Company

Comment:	Response:
1. Boeing must provide case histories on the use of cow manure for the remediation of perchlorate in situations similar to those present at the Santa Susana Field Laboratory.	1. Boeing is conducting bench-scale, and potentially field-scale studies to better establish what compound will be used to aid in degrading perchlorate. The bench-scale test does not include the use of cow manure, but other electron donor materials, such as citric acid (see Appendix C). Several case studies, supporting the degradation of perchlorate, are included in the HVIM Amendment as Appendix B.
2. Boeing must be made aware that site-specific, individual Waste Discharge Requirements (WDRs) will be required by the Regional Board for the aboveground bioremediation of any perchlorate (or other constituent) contaminated soil. Boeing must initiate the WDR process by immediately submitting a Report of Waste Discharge to operate a land treatment unit.	2. Based on a July 21 teleconference, the RWQCB was evaluating whether a General or Site-specific WDR would be required to bioremediate perchlorate-impacted soil, either in situ or ex situ. Based on numerous conversations with the RWQCB, it appears a Site-specific WDR will be required. Boeing is completing and will be submitting a WDR application to the RWQCB as soon as possible.
3. Although the use of shot-crete or epoxy sealant is accepted for sealing contaminated bedrock, this will create an extended period of quality control, inspection, and maintenance.	3. Boeing is aware of potential long-term commitments that may be necessary if Shot-crete or epoxy sealant is used to seal bedrock. Bedrock sealing will only be considered if no other options exist.

Appendix A

Happy Valley Interim Measures Work Plan Addendum Amendment
Santa Susana Field Laboratory

Response to Comments in RWQCB Letter dated July 15, 2003
Prepared by MWH for The Boeing Company

	Comment:		Response:
4.	Boeing must provide details of how they propose to conduct the simulated rain event, flooding, and runoff, and capture study for the evaluation of perchlorate transport in surface water following source area excavation.	4.	Subsection 3.2, Table 3, and Figure 4 of the HVIM Amendment provide details on the simulated rainfall event sampling process. The intent is not to flood the drainage or cause significant runoff. The sampling is intended to provide a "field screening" of potential perchlorate concentrations in drainage surface water in isolated portions of the Happy Valley drainage.
5.	Boeing must install proper drainage controls during excavation to prevent contaminated runoff from entering surface watercourses, such as ½-round corrugated metal pipe, berms, or sandbags. The drainage controls must be designed for a 25-year, 24-hour duration storm, at minimum; and	5.	Appropriate controls will be implemented to minimize runoff. Some controls will be designed for a 25-year, 24-hour storm event, although it is not anticipated, based on historical conditions in Happy Valley. These controls are presented in Subsections 3.1 and 3.3 of the HVIM Amendment.
6.	Please require that Boeing use clean soil as backfill in all excavations. "Clean soil" is defined as remediated soil containing contaminants which are at, or below, the Regional Board's May 1996 *Interim Site Assessment and Cleanup Guidebook* cleanup goals to protect groundwater quality. The top two feet of backfill must be uncontaminated, imported soils in order to prevent surface water contamination.	6.	Boeing will use the RWQCB's May 1996 *Interim Site Assessment and Cleanup Guidebook*, as appropriate, to evaluate potential backfill materials. Subsection 3.1 of the HVIM Amendment details potential backfill procedures.

Prepared for:

Aerojet
Rancho Cordova, California

AREA 41 EXPANDED FIELD TRIAL: BIOREMEDIATION OF SOILS WITH HIGH PERCHLORATE LEVELS BY APPLYING COMPOSTED MANURE

FINAL REPORT

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EXECUTIVE SUMMARY

Area 41 was utilized from 1960 to 1970 for burning waste materials from solid rocket motor production, resulting in residual perchlorate in soils within the former burn areas. A detailed transect study of the distribution of perchlorate within these former burn areas demonstrated that residual perchlorate in soils was at a small number of readily identifiable bare areas. In these bare areas perchlorate concentrations of tens to thousands of mg/kg were observed. Although these constitute only a small fraction of the total area of the former burn sites, we estimated that they contained 80% of the total mass of perchlorate present in soils at Area 41. Removal of these hotspots would therefore remove both most of the perchlorate mass, and all of the locations where perchlorate concentrations exceeded the present or probable future remediation goals for residential soils.

We conducted field trials during 1999/2000 of two methods of on-site remediation of these perchlorate hotspots. The first field trial consisted of excavation and anaerobic composting with manure and bulking agents. The second field trial consisted of simply applying a layer of manure to the soil surface and allowing sufficient time – at least one wet/dry season - for perchlorate biodegradation to occur. Both methods were successful. The simplicity and success of the later method, when combined with our proven ability to identify locations of high perchlorate, suggested that expanding the field trial of the surface application method by identifying and treating all of the bare areas with significant perchlorate would greatly simplify future remediation efforts at Area 41.

Accordingly, with agency approval we expanded the field trial during April and May 2001 by: (1) conducting a systematic mapping and analysis of all suspect areas; (2) excavating high level bare area cores and mixing in composted manure and calcium magnesium acetate; (3) covering the surface of these and all other bare areas with detectable perchlorate with 6-12 inches of composted cow manure; and (4) saturating the compost overlays with water. Approximately 200 locations were sampled, of which 10 consisted of high-level bare areas treated by excavation and mixing, and 65 of bare areas with low levels of perchlorate treated by a simple overlay of composted manure. The centers of eleven of the treated areas were marked with fenceposts so the same spot could be relocated for performance monitoring.

Area 41 was inspected and performance monitoring soil samples collected on April 5, 2002. Although the compost layer at most of the performance monitoring sites had been disturbed by range cattle, the average perchlorate concentration in soils at the monitoring locations had declined from 452 to 1.4 mg/kg, a greater than 96% reduction.

1. INTRODUCTION AND BACKGROUND

Figure 1. Stream cut illustrating the shallow soils overlying Salt Springs Slate bedrock at Area 41

Area 41 comprises 550 acres of gently rolling grazing land at the western margin of the foothills of the Sierra Nevada Mountains situated approximately one mile east of Aerojet's Main Plant (see Plate 1, Location Map). No significant development exists around Area 41 as it is surrounded by thousands of acres of rangeland. Fine-grained soils (silty-clay to clayey-silt) at the site are typically less than eight inches think and overly vertically-tilted metasedimentary rock of the Salt Springs Slate formation, as shown in Figure 1.

From 1960 to 1970, under permit from State agencies, Aerojet open-burned waste detonable materials from rocket manufacturing at Area 41. The waste stream, consisting primarily of a mixture of ammonium perchlorate, aluminum powder and TCE, was placed in isolated piles and ignited. Cleanup after burning activities terminated consisted of limited scraping of topsoil and removal of ash and solid debris.

2. TRANSECT STUDY

Based on targeted sampling of soils during the 1985 Historic, 1992 Stage 1 and the 1996 Stage 2 site investigations, it was initially assumed that significant areas of the Area 41 were impacted by moderate to high levels of residual perchlorate, and that extensive soil removal would be required to remediate the impacted areas. However, limited additional sampling strongly suggested that significant perchlorate contamination within burn sites was limited to a very small proportion of the visibly impacted areas, and that these locations were readily identifiable in the field. The transect study was designed to rigorously test this new hypothesis on a much finer scale than had been done previously.

Source Sites 46B, 48B, and 56B were the primary locations of oxidizer burn operations (see Plate 1), and were the areas with the greatest number of perchlorate detections in soils from the previous site investigations of Area 41. Accordingly, they were selected for transect sampling. Samples were collected at regularly spaced intervals along five transects totaling 2000 feet in length and covering approximately 3 acres (including the area covered by the off-transect targeted sampling). The transects bisected the potential source sites, and were located in areas of the greatest amount of burn activities and soil disturbance as determined from aerial photographs and mapping conducted during the Stage 2 Investigation. In addition to on-transect sampling, samples were also collected from visibly impacted locations (bare areas, locations with fused soil or metal slag, or other evidence that burning had occurred) within 40 feet on either side of the transect. 255 soil samples were collected and analyzed for perchlorate. Detailed maps were prepared of the transects which included surface features, sample locations, soil depths, and perchlorate analysis results. This sampling method allowed us to determine the spatially averaged concentration of perchlorate from the on-transect samples, and to relate visual observations to perchlorate concentration in the off-transect samples. Plate 2 is a representative transect map.

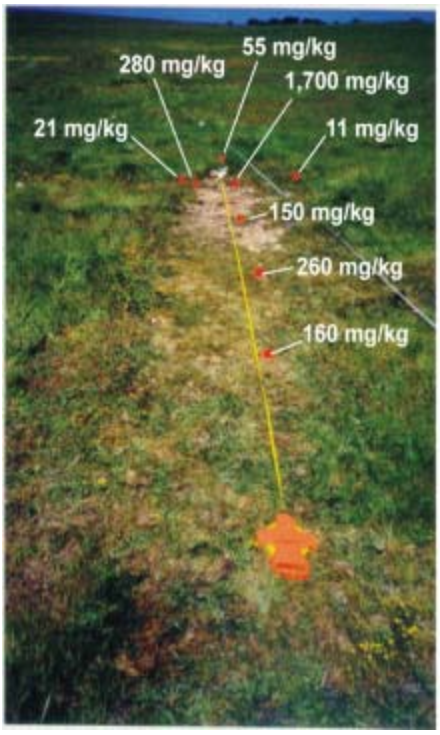

Figure 2: Typical large bare area with a high concentration of perchlorate. 1,700 mg/kg in the core with rapid attenuation towards its margins.

Three types of perchlorate soil impacts were identified at Area 41 during the transect study:

High Level Bare areas typically fringed by reduced or stressed vegetation impacted with high levels of perchlorate. Perchlorate soil concentrations ranged from about 50 mg/kg to 11,000 mg/kg, but the total surface area of high level contamination is very limited. Perchlorate in soils at concentrations greater that 40 or 50 mg/kg apparently prevents germination of grass seeds hence the

correlation between areas devoid of grasses and elevation residual perchlorate in soil.

An example of a large high level bare area is shown in Figure 2, while Plate 3 is a detailed map of the distribution of perchlorate at a cluster of high level sites prior to treatment during the initial phase of the surface application field trial. In detail, these locations typically consisted of an isolated central bare area, where high surface perchlorate concentrations drop to less than 10 mg/kg at depths of less than one foot. The actual soil depth is generally only a few inches, but near-surface bedrock consists of vertically tilted, weathered slate, and perchlorate had penetrated the bedrock in narrow clay lenses separating layers of this slate. A fringe of reduced and apparently stressed vegetation surrounded the central bare area, with surface perchlorate concentrations less than about 50 mg/kg, declining to less than 1 mg/kg over the space of a few feet. There is no detectable perchlorate at depths greater than a few inches in this fringe area. Perchlorate has been retained in the near surface in the fringe area due to the low permeability of the soils, and wetting/drying cycles, which wick soluble salts to the soil surface in the spring and summer. The fringe area has probably resulted from dispersion and runoff from the central bare area, as evidenced by its elongation downslope.

These high-level bare areas were rare, occupying only about 300 square feet of the total area covered by transect sampling of 130,000 square feet, and only a small proportion of bare areas have high levels of perchlorate. In spite of the limited area occupied by high level bare areas, these sites contain as much as 80% or more of the total mass of perchlorate present in soils at Area 41.

Low-Level Burn Site Persistent, low levels of residual perchlorate are present at burn sites. These can be bare, but more commonly vegetation is present but appears stressed or otherwise reduced. This category is by far the predominant type of residual perchlorate in surface soil at Area 41. Low-level burn site impacts probably resulted from normal burning of propellant and leaching of residual perchlorate from ash. Perchlorate soil concentrations at the Low Level Burn Sites averaged 0.81 mg/kg.

Low-Level Non-Burn Site Occasional areas of low-level perchlorate soil impacts in low areas and deeper soils were detected downslope of burn areas. These locations are restricted to a limited number of particular areas located downslope from areas of

contamination. Only deeper soils appear to be affected, as infiltration into the more typical shallow soils is extremely limited. This secondary contamination probably occurred predominately during or soon after burning operations.

The key observation of the transect study was that the greatest mass of perchlorate in Area 41 soils is concentrated in a very small volume of soil. Moreover, we could now confidently visually locate areas of probable high perchlorate (areas devoid of vegetation), and could also confidently predict that areas of the site without bare spots or sparse vegetation would contain little or no perchlorate. Remediation of the high-level locations would eliminate both the greatest mass of perchlorate and all locations likely to exceed the present or future remediation goals for perchlorate based on health risks from soils.

3.0 FIELD TRIAL: REMEDIATION OF PERCHLORATE IN SURFACE SOILS BY THE APPLICATION OF MANURE

We tested a simple method of bioremediating these isolated locations of high perchlorate in soil that takes full advantage of the unique features of Area 41 – the small size of the areas in which perchlorate is present, the shallow soils, and the occurrence of perchlorate a depths greater than a few inches only at the central bare areas, which are at most a few feet in diameter. The method consisted of simply applying water-saturated cow manure to the soil surface, and allowing bacteria, moisture, and organic material from the manure layer to leach into the soil, aided by rainfall in the winter. Perchlorate-reducing bacteria present in manure and soil were then provided with the proper conditions of food, moisture, and reduced oxygen without requiring any additional soil disturbance.

On October 28/29, 1999, test plots consisting of two isolated areas of elevated perchlorate in surface soils were treated by applying 3-4 inches and 12 inches of manure, respectively, to the soil surface to determine if this simple application would be sufficient to create the conditions necessary for the biological destruction of perchlorate, both at the soil surface and at depth. The distribution of perchlorate was mapped in detail (see Plate

Figure 3. Test plot January 2000.

3), after which the manure layers were applied.

Sampling baselines were located, and performance monitoring samples were collected at regularly spaced intervals at approximately 3 month intervals. By March 2002 perchlorate was undetectable in the bare area margins had declined to below the detection limit, and residual perchlorate was confined to the bare area cores. This was the case for both the test plot with a 12-inch thick manure layer, and the test plot with a 3-4 inch thick manure layer. These results demonstrated that perchlorate can be readily remediated in surface soils with a modest layer of manure, but that complete remediation of perchlorate in deeper levels required either more time, or limited excavation and mixing.

The initial phase of the field trial demonstrated that perchlorate in the surface soils at Area 41 can be remediated using a very simple and non-disruptive technique. An added advantage was that the soil conditions were improved by the remediation process. Accordingly, we proposed that the field trial be expanded to include all of the bare areas in advance of a cleanup standard for perchlorate in soils.

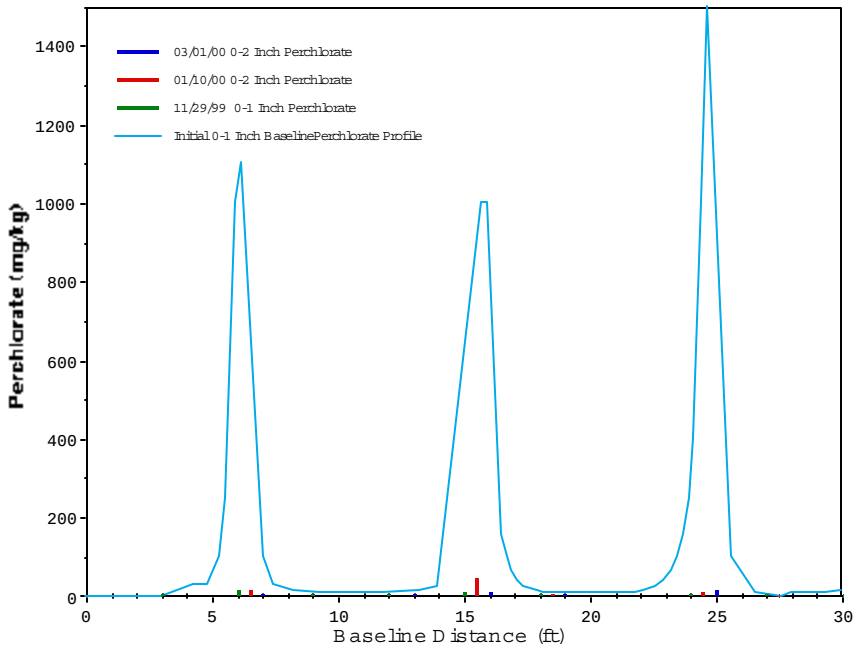

Figure 4. Test Plot Sampling Results Summary. The width of the colored line is equivalent to the width of the actual soil sample - two inches. Note that as of March 1, residual perchlorate is only present at the site of original perchlorate maxima centered at the bare area cores.

4.0 EXPANDED FIELD TRIAL: BIOREMEDIATION OF SOILS WITH HIGH PERCHLORATE LEVELS BY APPLYING COMPOSTED MANURE

4.1 Field Trial Establishment Area 41 was divided into Treatment Areas as shown in Plate 4 based on historic use records, aerial photographs, and previous site investigations. A, B, C, and D were the primary Treatment Areas for perchlorate-TCE sludge, and bare areas with elevated perchlorate had been identified in each of them. Treatment Areas E, F, and G were secondary, and although no bare areas with perchlorate were observed in them in a reconnaissance survey, historical records indicate that perchlorate-bearing materials may have been disposed of within them. Our procedure was to survey and treat each treatment area in sequence. Locations of bare areas were located on enlargements of aerial photographs taken in 1995 and in the field by a systematic search. A surface soil sample of the center of each bare area or other potential location was collected and analyzed following the recently improved perchlorate-specific electrode extraction and analysis procedure that has been used extensively in previous studies of the distribution of perchlorate in Area 41 soils. Bare areas with detectable perchlorate were flagged, the margins of the area to be covered with manure outlined for treatment and the location noted on the aerial photograph.

Figure 5. Marking the perimeter of a bare area for applying composted manure.

Figure 6. Excavating the bare area core.

Non-composted manure was used during the original field trial of the surface application method with good results. For the expansion

of the field trial composted manure was substituted to alleviate undesirable weed species seeds in non-composted manure and regulatory agency concerns regarding the presence of mobile nitrogen compounds and possible pathogenic organisms. Composted manure differed from the non-composted manure used previously in that it was more compressible, probably due to the greater degree of decomposition of woody plant tissue. As a result, the compost layers applied to the soil surface compacted considerably during the initial watering, from an original 6-12 inches down to 3-6 inches.

Figure 7. CMA addition to excavation.

Bare areas with more than residential preliminary remediation goal for perchlorate of 39 mg/kg (USEPA PRG tables, 2001) were excavated with a backhoe in order to speed up bioremediation by mixing in manure. This would prevent the likely persistence of perchlorate in deeper soils of the bare area cores. The surface soil was excavated with the backhoe until competent bedrock was reached. Approximately 10 lbs. of solid CMA (calcium magnesium acetate) were added to the bottom of the excavation, and then backfilled with a mixture of soil and compost. The CMA was used to provide additional carbon for penetration into the underlying bedrock, as well as to increase permeability and raise the pH of the acidic clays (generally about 4.5 -5) to the optimum neutral pH for perchlorate-reducing bacteria.

Figure 8. Treated area illustrating compaction and lack of vegetation due to cattle scratching on the fencepost.

Once the core excavations had been backfilled, a layer of composted manure at least 6-12 inches thick at the center was applied. This layer was several feet larger in diameter than the bare area and affected fringe (as demarcated by reduced vegetation). The compost layer was then saturated with water to initiate biological activity.

Fieldwork took place in March and April 2001. Approximately two hundred locations of potentially elevated perchlorate concentrations were sampled, of which seventy-five were determined to have perchlorate at concentrations greater than the field screening detection limit of 0.5 mg/kg. Of these seventy-five samples nine had concentrations greater than 39 mg/kg. As anticipated, the greatest numbers of locations requiring treatment were in Treatment Areas B and D, with lesser numbers in Treatment Areas A and C. No areas requiring treatment were discovered in the secondary Treatment Areas E, F, and G, but four locations requiring treatment were discovered alongside the major access road. The location of the treated sites is shown in Plate 4. Approximately 250 cubic yards of composted manure were required. As proposed in the work plan, 25% of the treated areas were to be marked with a metal fence post for performance sampling. Metal fence posts were driven in the center of eleven of the treated areas to mark the location for performance sampling.

In December 2001 the treatment areas were hand seeded with Regreen, a sterile grass widely used in reclaiming disturbed soils.

4.2 Results The eleven locations marked with fenceposts were resampled on May 15, 2002. Samples were taken adjacent to the fenceposts, which marked the center of the original bare area and the location of the original sampling.

Figure 9. Lush grass on undisturbed treatment area.

The compost overlays and the fence posts marking the locations for performance monitoring proved attractive to cattle. The cattle congregated at the treated sites further compacting, and to some extent, scattering the compost overlays. However, since all the locations with significant perchlorate (>39 ppm) were treated by excavating and backfilling, they were minimally affected by compaction and scattering. Locations in which cattle did not congregate generally

had an extensive vegetation cover due to seed germination in the composted soil.

Perchlorate concentration in the treatment areas had been greatly reduced, as shown in Table 1 below, with an average reduction of approximately 96% with 7 of the 11 sites achieving 98.7% reduction or more. Performance monitoring sites with greater than 39 mg/kg original perchlorate were excavated and mixed with manure and CMA. Those 7 sites had an average reduction rate of 99.2% indicating the advantage of mixing and CMA addition. For most locations the reduction was almost complete, with residual perchlorate concentrations of less than 1 mg/kg. The highest post-treatment levels were observed at locations with low original concentrations that had been heavily disturbed by cattle (sites 63B-2 and 46B-1).

Location ID	Pre-Treatment Perchlorate (mg/kg)	04/05/2002 Perchlorate (mg/kg)	Reduction
46B-1	80	3.7	95.4%
48B-1	350	<0.40	>99.9%
48B-2	12	<0.20	>98.8%
49B-1	17	0.22	98.7%
56B-1	3500	2.5	99.9%
56B-2	350	0.3	99.9%
56B-3	140	0.19	99.9%
56B-4	410	<0.040	100%
63B-1	21	0.77	96.3%
63B-2	65	0.17	99.7%
63B-3	24	6.8	71.6%
Average	452	1.4	96.4%

Table 1. Results of Performance Monitoring

4. DISCUSSION

At Area 41 the greatest mass of perchlorate was found to be concentrated in high amounts in a small number of bare areas. The 1999 Transect Study demonstrated that we could locate these

high perchlorate areas. Over 200 sites were sampled and 65 sites treated with approximately 250 cubic yards of composted manure. Based on our systematic sampling of Area 41 we conclude that all of the high level bare areas have been bioremediated to levels below the USEPA Residential Soil PRG by the simple application of composted cow manure. The situation at Area 41 was unique in its combination of very shallow soils and small areas of high concentrations and the techniques used here may not be widely applicable. However, we have gained considerable insight into the minimum requirements for successful bioremediation of perchlorate in soil, and less intensive methods than have heretofore been employed may be successful elsewhere.

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Borch, RS and SL Neville (2001) Area 41 Expanded Field Trial: Bioremediation of Soils with High Perchlorate Levels by Applying Composted Manure.

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USEPA (1992) Supplemental Guidance to RAGS: Calculating the Concentration Term. Intermittent Bulletin Volume 1, Number 1.

Pilot Scale In-Situ Bioremediation Of Perchlorate-Contaminated Soils At The Longhorn Army Ammunition Plant

INVESTIGATORS

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Contract # : DAAA09-00-C-0060

ABSTRACT

Treatability studies were conducted to identify suitable carbon sources for the cleanup of perchlorate-contaminated soils at the Longhorn Army Ammunition Plant (LHAAP) in Karnack, Texas. A series of bench-scale experiments to measure the kinetics of perchlorate removal in LHAAP soil were conducted. The use of microorganisms to enhance bioremediation (biostimulation) was evaluated by applying such organic amendments as poultry manure, cow manure, horse manure, cotton waste, methanol and ethanol. The different amendments stimulated the biodegradation of perchlorate in the contaminated soils, with cotton waste resulting in slower rates compared to the other carbon sources. A series of column tests evaluating the transport behavior of ethanol in LHAAP soil suggested that the soil has very low ability to adsorb carbon. Based on the results of these initial treatability studies, a field demonstration study was conducted at the LHAAP site. Three carbon sources (ethanol, horse and chicken manure) were selected for pilot testing at the site.

The distribution of perchlorate across the plots varied widely and the maximum concentration of perchlorate in the selected treatment plots at the start of the pilot study was 400 mg/kg. The field demonstration started in October 2000. Six identical treatment plots (4.57 x 2.74 m) and one control cell (5.5 x 5.5 m) were sectioned off (isolated) using plastic liners. Duplicate cells were treated with the same predetermined concentration of each amendment and no amendment was added to the control cell. Water was applied to all 7 plots to achieve complete saturation only down to the desired treatment depths below ground surface (bgs). Maximum rates of perchlorate removal at the top layer during the start of the test are in the range of 6-7 mg/kg-soil/day. After 120-days of bioremediation, perchlorate concentrations in soil were reduced from initial values ranging from 8.4 to 295.3 mg/kg, down to 0.0 to 223.4 mg/kg. After ten months, we observed complete removal of perchlorate in the surface soils and varied reduction in the deeper layers. At the termination of the pilot study, the concentration of perchlorate in the wettest cells (except for the control) had decreased to non-detectable levels at all treatment depths. The effectiveness of the process varied with the type of organic amendment, wetness of the soils, and depth. It was found that under field conditions, horse manure and ethanol were superior carbon amendments. The results of this pilot study demonstrate that perchlorate-contaminated soils can be treated in-situ by applying the cost-effective techniques we have developed to deliver nutrient amendments to desired depths.

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I. RATIONALE

Background

Past industrial operations, testing, and training activities at numerous Department of Defense (DoD) installations have resulted in the release of many toxic chemicals substances into the soil, surface water, and groundwater. The use of cost-effective technologies to remediate impacted sites assists the U.S. military in meeting its stewardship goals while conserving resources that can be directed to maintaining its readiness capability.

The Longhorn Army Ammunition Plant (LHAAP) site is located in a moist, sub-humid to humid, mild climate with an average annual rainfall of 46 inches, which is fairly evenly distributed throughout the year. The depth to groundwater across the facility ranges from 1 to 70 ft below ground surface, with typical depth to groundwater being 12 to 16 feet. Groundwater generally occurs under unconfined conditions with frequent occurrence of perched and local confining conditions due to the high clay content and highly variable stratigraphy. LHAAP is presently inactive and scheduled to be transferred to the US fish and wildlife service. A 1998 Remedial Investigation/Feasibility Study (RI/FS) for the LHAAP indicates that perchlorate has seriously impacted surface water, groundwater and soils at the site.

Located in the Production Area of Longhorn AAP and in the watershed area of Goose Prairie Creek is Building 25-C. Building 25-C has been identified as a building where ammonium perchlorate was ground prior to being incorporated in rocket motors and flare propellants. A characterization of perchlorate concentrations around building 25-C prior to remedial action is presented in Table 1 and the corresponding soil types in the sampling area is provided in Table 2.

TABLE 1.
Measured perchlorate concentrations around building 25-C at the Longhorn Army Ammunition Plant, (μg/kg), (Sampled 18 August 1998)

		Sampling Location								
		25C1	25C2	25C3	25C4	25C5	25C6	25C7	25C8	25C9
Sampling Depths (ft)	0-0.5'	27,500	84,800	1,920	1,390	2,900	6,050/ 5,880 QC/ 11,000 QA	140,000	1,640	84,200
	4'-5'	58,800	335	22.1/ 23.1QC/ <40QA	36,900	50,700	165,000	3,690	21,900	81,600
	9'-10'	10,700	5,720	12,300	3,570	15,200	118,000	2,310	14,400	8,090

Source: 1998 Remedial Investigation/Feasibility Study (RI/FS) for LHAAP, Texas

The Texas Environmental Protection Division and the U.S. Army have been seeking low cost remedial technologies for the clean up of perchlorate, TNT, and other contaminants at this site. The removal of perchlorate from soils using phytoremediation was considered as one alternative. However, this approach is a very slow process at this site because the tree roots that promote rhizodegradation are not evenly spread out in contaminated soil, thus limiting rhizosphere activity in the absence of organic carbon.

TABLE 2.
Soil sampling description for sampling around building 25-C [Companion table to Table]

		Sampling Location								
		25C1	25C2	25C3	25C4	25C5	25C6	25C7	25C8	25C9
Sampling Depths (ft)	0-0.5'	Yellow Brown silty Sand	Tan silty Sand	Yellow Brown/ Gray silty Sand	Light Brown silty Sand	Brown Silty Sand	Yellow Brown silty Sand	Brown Sand	Mixed Sand/ Gravel	Yellow Brown silty Sand
	4'-5'	Gray-red stiff Clay	Gray clayey Sand	Gray clayey silty Sand (wet)	Gray silty Sand	Mottled Brown/ Gray clayey silty Sand	Gray silty Sand	Gray silty Sand w/dk brown woody type fiber mixed	Brown Gray silty Sand	Mottled Brown/ Gray silty Sand
	9'-10'	Gray clayey Sand (moist)	Yellow Brown clayey Sand (wet)	Brown Sand (wet)	Gray clayey Sand	Gray/Brown clayey Sand	Gray silty Sand	Brown silty Sand (wet)	Gray silty Sand	Gray silty Sand

Source: 1998 Remedial Investigation/Feasibility Study (RI/FS) for LHAAP, Texas

Feasible alternative

A large body of literature suggests that ubiquitous perchlorate-reducing microorganisms are present in groundwater, soils, and sediments. Our work in phytoremediation has confirmed that microbial systems in the rhizosphere contribute significantly to perchlorate transformation. Based on this information, we proceeded to develop a biotreatment system for perchlorate-contaminated soils that addresses the shortcomings of phytoremediation treatment at this site.

The technology employs a system for surface application of amendments that enhance in-situ bioremediation of perchlorate at defined depths. The sandy nature of the topsoils around Building 25C (Table 2) presents favorable conditions for this approach. The biotreatment system is essentially a composting system with suitable carbon sources added at the surface and allowed to infiltrate the soil profile.

The technology is relatively inexpensive and sufficiently effective that it can be implemented on a large scale to clean up many acres of perchlorate contamination in soils within a very short

time. Adding a suitable carbon (electron) source to the soil contaminated with perchlorate results in the enhancement of transformation of perchlorate to chloride. We have identified and tested the best amendments [preliminary bench scale evaluation] for LHAAP in completed laboratory tests using perchlorate-contaminated soils collected from this site. Since soils are very heterogeneous, different types of amendments are required to formulate the most effective system and achieve optimum degradation rates.

Demonstration and validation data of biotreatment systems for perchlorate-contaminated soils is a special need that supports DoD's cleanup efforts and transfer of the technology. Composting-biotreatment like phytoremediation has very low initial startup and maintenance costs, and can attenuate contaminant concentrations to very low levels. Combined with other technologies intended for source removal, this approach can be very effective as a long-range strategy. Therefore, the overall goals of this project were to develop and evaluate the Composting-Biotreatment technology and transfer the technology through an onsite pilot demonstration at LHAAP.

II. OBJECTIVES

- Refine an in-situ bioremediation approach using bench scale testing that will lead to final plans for field scale demonstration.
- Implement field scale demonstrations of surface application of amendments to treat perchlorate-contaminated soils.
- Evaluate feasibility of *in-situ* bioremediation of the vadose zone.
- Conduct batch studies to evaluate kinetics of perchlorate degradation for each carbon source tested in the field.
- Select an inexpensive and effective carbon source that will provide for rapid perchlorate reduction, specifically in soils at the LHAAP.
- Determine the maximum depth to which the soils at the LHAAP site can be treated using Composting-Biotreatment technology.

III. REFINEMENT OF TECHNOLOGY IMPLEMENTATION USING BENCH-SCALE TESTING

A series of bench-scale tests were conducted to evaluate the amount of amendment and the type of amendment that would be most suitable for the soils at LHAAP. Soil samples were obtained from LHAAP around building 25-C and transported to our laboratory. Several organic amendments including cow manure, chicken litter, cotton gin waste, methanol, molasses, and ethanol were evaluated. Table 3 summarizes the types of experiments and duration. Individual experimental procedures and their results are described in the following sections.

TABLE 3.
Summary of bench – scale experiments that were conducted to evaluate amendment-LHAAP soil interactions.[1]

Date of Exp. Start – End	Treatments
May 5, 2000 – June 14-15	LHAAP Soil+ [CM, CL, CGT, MeOH, EtOH][1]
Undated	LHAAP Soil slurry+Amendment [MeOH] Run time 31d
June 15 – July 20	LHAAP Soil slurry+[CL, CGT] Run time 35d
June 28 – July 21	LHAAP Soil slurry+[CM] Run time 22d
Undated	LHAAP Soil+[CL, CGT, Mol] Run time 3.2d
July 25	TIC and TOC on CL extracts in DI water
July 27 – Aug 4	LHAAP Soil+GW+[CL different levels] Run time 8 d
July 28	LHAAP GW+[CL] Run time = 10d

[1]Legend of symbols used:
CM – Cow manure
CME – Cow manure extract prepared by mixing raw cow manure with DI water
CL – Chicken litter [or manure]
CLE – Chicken litter extract prepared by mixing chicken litter with DI water
CGT – Cotton gin trash
DI – Deionized water
MeOH – Methanol
Mol – Molasses
GW – Ground water [from the LHAAP site]

May 5 – Experiment (Refer to Table 3)

Procedure: CME and CLE were prepared by mixing CM and CL with DI water in a ratio of 1:1 (v/v). CGT extract was prepared by mixing CGT with DI water at a 1:2 (v/v) ratio. The LHAAP soil was used in this trial. Water used in this mix was ICT-8 water from LHAAP (contains about 35 ppm perchlorate). In addition DI water was used. Samples were kept in 500 mL Erlenmeyer

flasks and allowed to sit at room temperature for 40 and 41 days before analysis. Table 4 below shows a list of treatments.

TABLE 4.
Summary of treatments and results obtained in bench-scale testing.

Tmt #	Treatment [100 mL DI water was added to each flask after treatment below was prepared]	Final Perchlorate concentration[1, 2] mg/kg	Perchlorate analysis date
1	250 g Soil + 250 mL CME	0.00	June 14
2	250 g Soil + 50 mL CME	0.26	June 15
3	250 g Soil + 50 mL CLE	0.00	June 15
4	250 g Soil + 50 mL CGT extract	0.00	June 15
5	250 g Soil + 50 mL MeOH (at 20% conc.)[3]	184.1	June 15
6	250 g Soil + 50 mL Mol	35.0	June 15
7	250 g Soil + 50 mL Diluted Mol (at 50% conc.)[3]	4.9	June 15
8	250 g Soil + 50 mL Diluted CME (at 50% conc.)[3]	0.26	June 15
9	250 g Soil + 50 mL Water [Control 1]	190.7	June 15
10	250 g Soil + 50 mL Water [Control 2]	187.4	June 15

[1]Average of 2 replicate analysis [not replicated treatment]
[2]Chromatogram says treatment – extracted with 250 mL DI water
[3]Dilutions performed with deionized water analysis showed no perchlorate.

June 15 – Experiment (Refer Table 3)

Procedure: Soil plus one gram chicken manure or one gram cotton waste plus 20 ppm perchlorate. Duplicate samples were sacrificed for perchlorate analysis at predetermined time intervals.

Results: The concentration of perchlorate in the soil slurry over a period of 35 days is shown in Figure 2. Dramatic reduction in perchlorate from 35 mg/L down to less than 1.0 mg/L within five days are seen in the chicken litter amended treatments. Thereafter the concentration remained close to zero in this treatment.

Cotton waste was less effective compared to chicken manure. The high amount of organic carbon and micronutrients in the chicken manure can be the reason for this effectiveness. Previous work has shown that in the presence of organic carbon, indigenous microorganisms are capable of using perchlorate as a terminal electron donor and transforming it to chlorate (Figure 2).

Figure 1. Influence of organic carbon (acetate) on perchlorate degradation in soils.

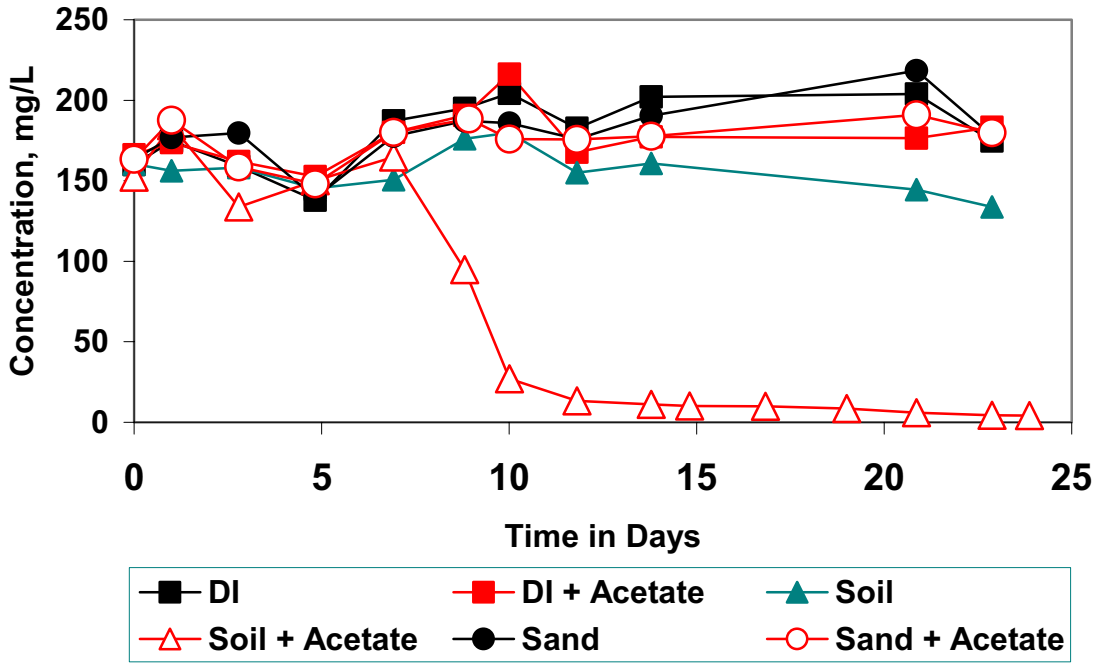
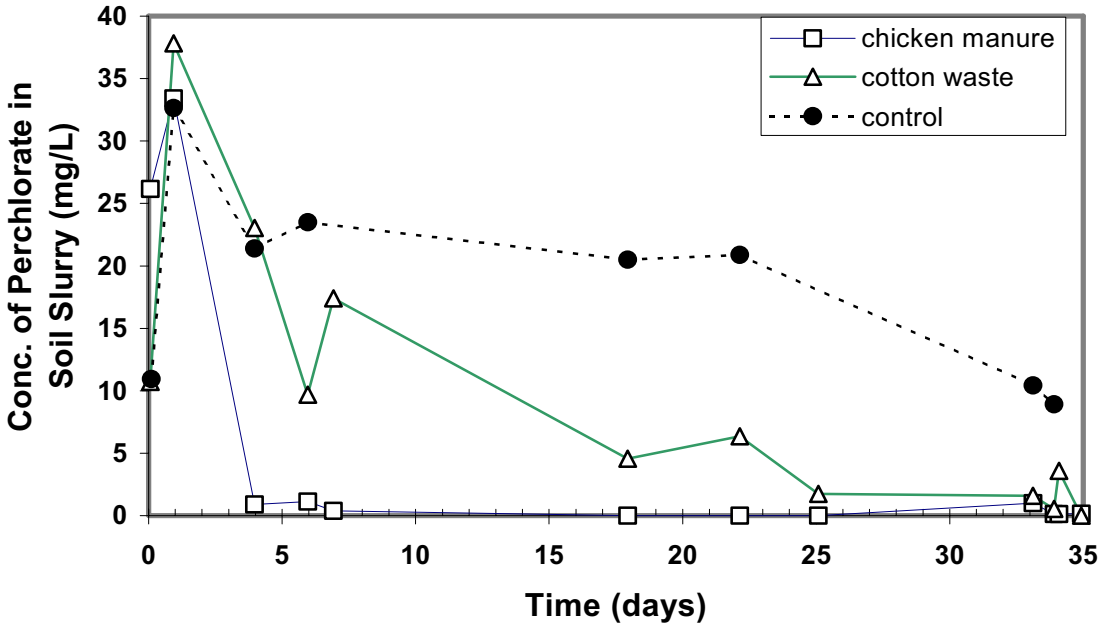


Figure 2. Biodegradation of Perchlorate
Flasks contained 25g Soil+1g Amendment, Control was Umamended

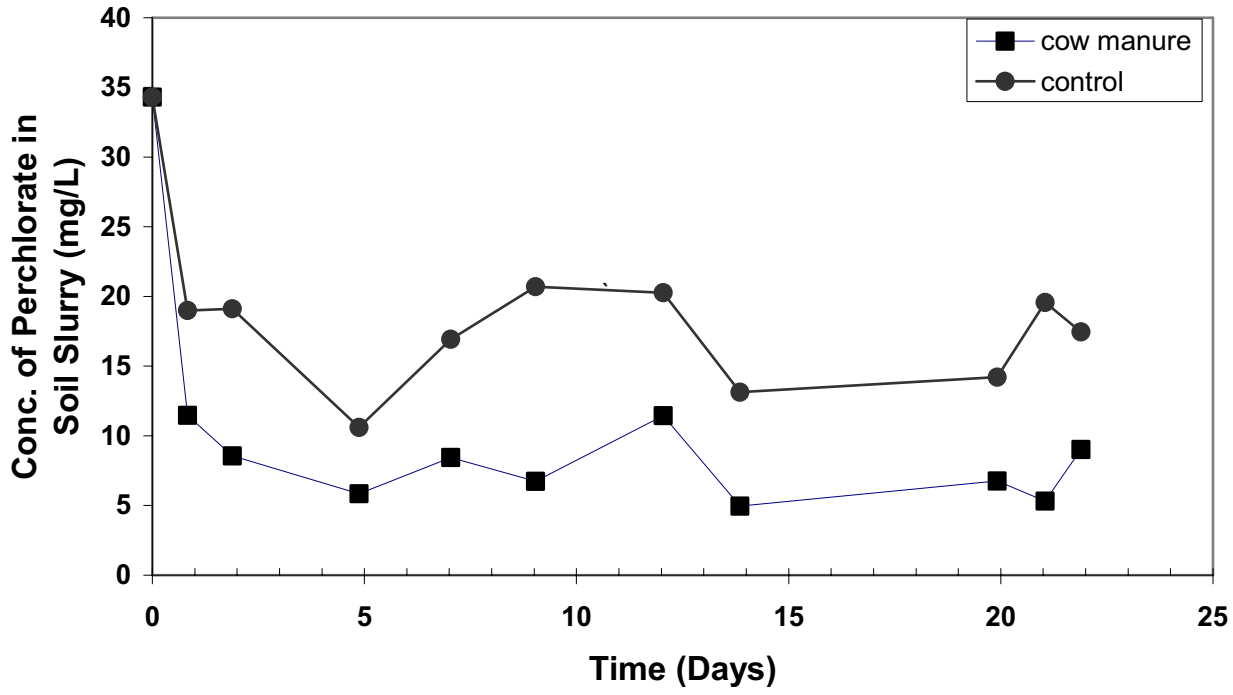


June 28 – Experiment (Refer Table 3)

Procedure: CME was prepared by mixing 500g of dry cow manure with 1 L of DI water. Treatment consisted of mixing 25 g of contaminated soil with 10 mL of CME+ ICT-8 LHAAP of perchlorate-contaminated water (34.3 ppm).

Results: Similar reduction in concentration of perchlorate is seen in the cow manure treated soil slurry (Figure 3). The concentration was reduced from initial values to stable values within three days. In the case of the control, the concentration stabilized at approximately 17 mg/L and remained at that level for the duration of the experiment. The cow manure amended treatment reduced to a lower level of approximately 7 mg/L where it stabilized (Figure 3).

Figure 3. Biodegradation of Perchlorate
Flasks contained 25g Soil + 10mL CME, Control was unamended



July 27 – Experiment (Refer Table 3)

Procedure: CME was prepared by mixing 500 g fresh cow manure with 1 L DI water. Different volumes of CME [0 to 32mL] were mixed with 25g of contaminated Soil and 25mL of GW [ICT-8]. Control was amended with DI water in a volume equal to the CME added to treatments. Flasks were incubated for eight days [July 27 - Aug 4] and analyzed.

Results:
The data obtained in the experiment is provided below in Table 5 for verification. The data have been summarized in Figure 4 following the table. The reduction in perchlorate concentration in various treatments ranged from 86.2 to 100%. In lower dosages of less than 1mL added to the sample solution (25 g soil + 25 mL GW), the removal was in the range of 86.2 to 89.5 % when compared to the controls.

At the higher dosage of cow manure extract (>2 mL per sample solution (25 g soil + 25 mL GW)), the removal was complete within the test period. There appeared to be little advantage in increasing the amount of cow manure extract added to the treatments (Table 5).

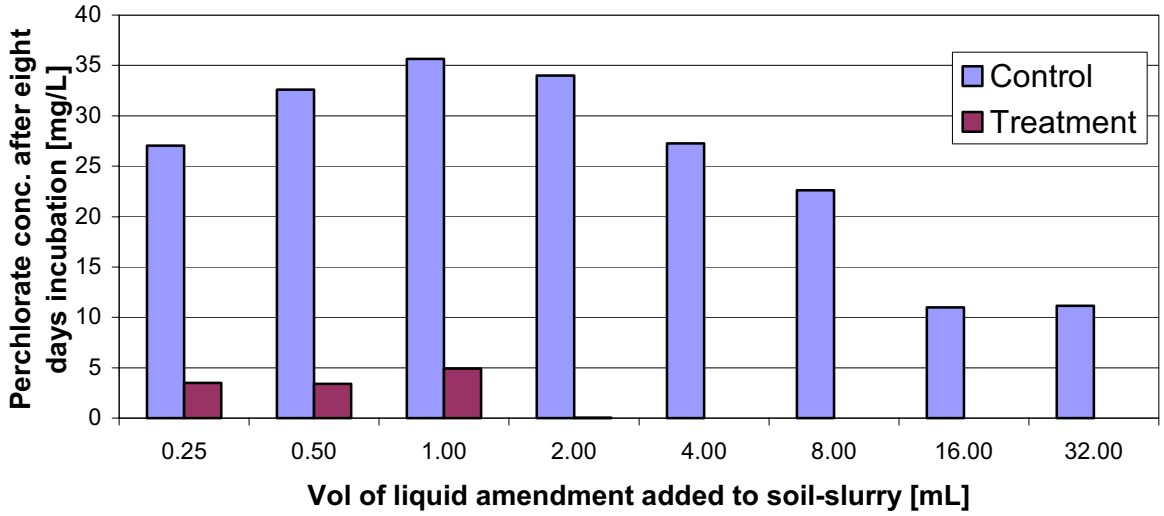
TABLE 5.
Experimental data from July 27: Treatments and concentrations

SAMPLE COMPOSITION:
25g soil (LHAAP), 25ml ICT-8, Different amounts of Cow manure and DI.
EXTRACT COMPOSTION:
Extract made from 500g of fresh cow manure and 1Liter of DI Water.
Prepared on 07/27/00,
Sampled on 8/4/00.

SAMPLE NAME	VOLUME	DILUTION	Conc. Rep1 mg/L	Conc. Rep 2 mg/L	Average Control.	Average Treatment. mg/kg
CM CONTROL1	0ml DI water	10	31.86	33.06	32.46	3.42
CM CONTROL2	0.25ml DI water	10	27.00	27.07	27.04	3.50
CM CONTROL3	0.5ml DI water	10	32.59	32.63	32.61	3.40
CM CONTROL4	1ml DI water	10	35.58	35.71	35.65	4.92
CM CONTROL5	2ml DI water	10	33.97	34.02	33.99	0.03
CM CONTROL6	4ml DI water	10	27.22	27.30	27.26	0.01
CM CONTROL7	8ml DI water	10	22.67	22.60	22.63	0.00
CM CONTROL8	16ml DI water	10	11.00	10.96	10.98	0.00
CM CONTROL9	32ml DI water	10	11.17	11.11	11.14	0.00
		TREATMENTS				
CM 1	0.25ml cow manure	2	3.42	3.40	3.41	
CM 1B	"	2	3.42	3.43	3.42	3.42
CM 2	0.25ml cow manure	2	3.41	3.69	3.55	
CM 2B	"	2	3.41	3.49	3.45	3.50
CM 3	0.5ml cow manure	2	3.40	3.36	3.38	
CM 3B	"	2	3.41	3.42	3.41	3.40
CM 4	1ml cow manure	2	6.31	6.36	6.33	
CM 4B	"	2	3.48	3.54	3.51	4.92
CM 5	2ml cow manure	2	0.00	0.00	0.00	
CM 5B	"	2	0.05	0.07	0.06	0.03
CM 6	4ml cow manure	2	0.00	0.00	0.00	
CM 6B	"	2	0.00	0.03	0.02	0.01
CM 7	8ml cow manure	2	0.00	0.01	0.00	

CM 7B	"	2	0.00	0.00	0.00	0.00
CM 8	16ml cow manure	2	0.00	0.00	0.00	
CM 8B	"	2	0.00	0.00	0.00	0.00
CM 9	32ml cow manure	2	0.00		0.00	
CM 9B	"	2	0.00	0.00	0.00	0.00

Figure 4. Effect of addition of different quantities of Cow Manure Extract on Perchlorate biodegradation



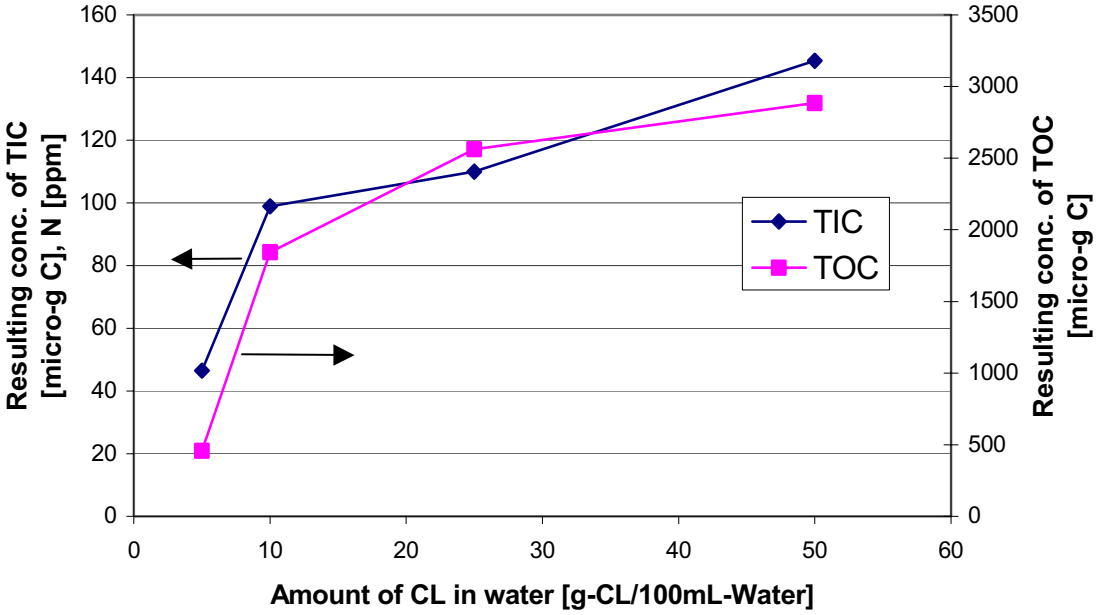
July 25 – TIC/TOC extraction experiment (Refer Table 3)

In order to determine the amount of extractable organic and inorganic carbon in the extracts, TIC/TOC were measured.

Procedure: Different quantities of fresh chicken litter was mixed with DI water to provide extractions of differing concentrations. TOC and TIC were measured on the resulting extracts. The chicken litter/water mixtures were stirred for 2 hours and then filtered with a regular coffee filter.

Results:
As expected, increasing the amount of chicken litter in the extract increased the total organic carbon (Figure 5). There appears to be a point of saturation at approximately 25 g/100 mL. The corresponding TOC extractable was 2600 µg in the 100 mL solution.

Figure 5. Extractable carbon from chicken litter at different mixture strenghts.



IV. FIELD SCALE DEMONSTRATION OF PERCHLORATE REMEDIATION

Objectives

The primary purpose of this part of the project was to determine if sub-surface microbial communities would transform perchlorate, thus demonstrating the feasibility of performing in-situ perchlorate remediation.

Pilot Scale Demonstration Procedures

The pilot scale demonstration study was conducted at a former pilot scale wastewater treatment plant on the LHAAP site and consisted of six 15 x 9 ft treatment plots and an 18 x 18 ft control plot (Figures 6, 7).

Previous soil analysis indicated that perchlorate concentration ranged from 36,200 to 144,000 μg/kg (0-2 ft). Perchlorate groundwater concentration was reported as 22,000 μg/L in one well located at 150 ft from the selected location for the field study. Forty-two soil cores were obtained from the site to determine spatial distribution of perchlorate in the soil and other soil parameters (e.g., TOC). Based on these data, cells to receive carbon source addition were identified. Each cell was tilled to ~12 inches and trenches were dug 24 inches deep to isolate each cell. An attempt to hydraulically isolate each cell was made by installing plastic liners vertically inside the trenches. Liners were hung from a metal frame grid that was installed between adjacent cells.

Solid carbon sources were added to each of the cells and mixed with the tilled soil (Figure 7), and ethanol was added with the water source. Water was added in two stages to saturate the soil down to 12 and then 24 inches. Water saturation was monitored using tensiometers installed at 12, 24, and 36 inches below land surface (Figure 8). Soil cores were periodically obtained at different depths for perchlorate analysis. In addition, oxidation-reduction potentials (ORP) were measured in multiple locations and depths in each cell. Each cell was covered during the incubation period.

Figure 6. Schematic of the pilot scale demonstration test layout.

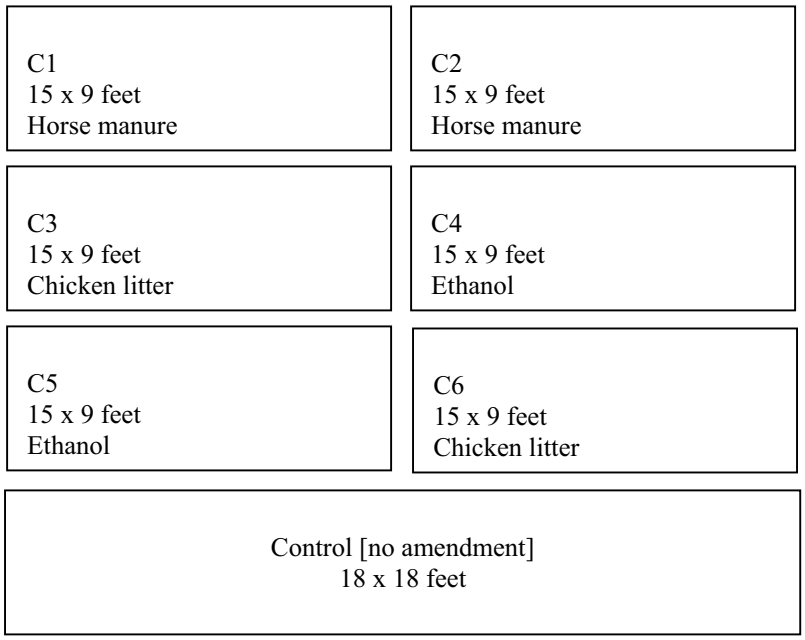


Figure 7. Photographic view of the pilot scale test layout immediately after addition of the liquid amendments.

Figure 8. Tensiometers installed in the pilot scale treatment plots.

RESULTS AND DISCUSSION

The addition of external carbon sources biostimulated the reduction of perchlorate in the site soil within 2 to 5 days. In the batch studies, perchlorate levels were typically reduced from 25-35 ppm to 0-5 ppm depending on the carbon source (Figures 1-3). Time course data for laboratory bench scale studies conducted with methanol and chicken manure indicated that these carbon sources, gave the highest perchlorate transformation rates (Figure 9). Similar data were obtained for ethanol (data not shown here). Ethanol was chosen as a carbon source due to it ease of availability and its greater efficacy to stimulate perchlorate transformation than methanol (determined from comparative studies conducted with different concentrations of ethanol and methanol).

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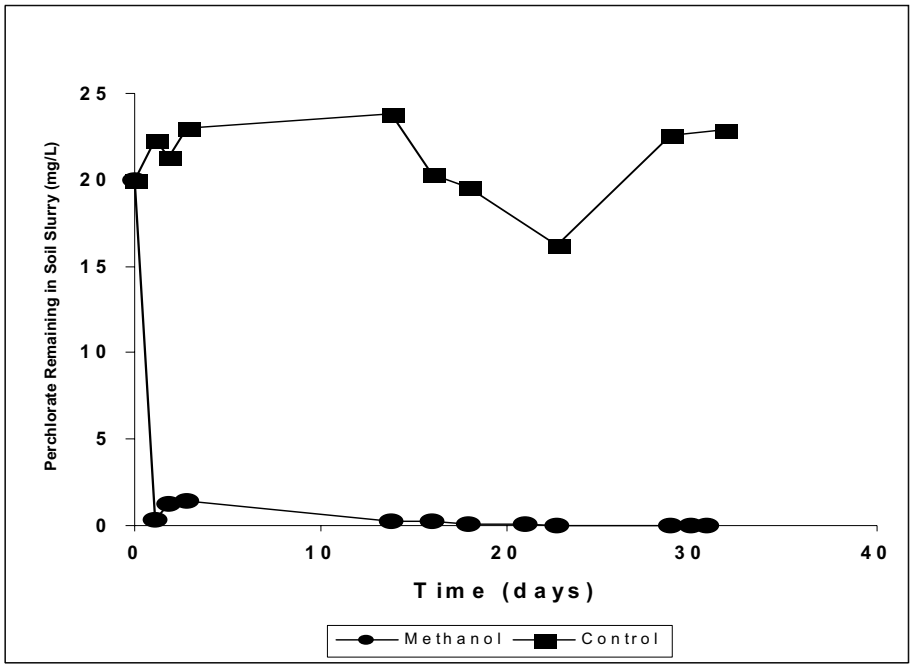
IGURE 9. Effect of methanol on the transformation of perchlorate in batch reactors using LHAAP site soil.



The LHAAP site soils at the pilot study location are characterized as silty clay (Richards, 1965). Tensiometers installed at different depths confirmed saturation to 0.91 m (3 ft) bgs. Negative oxidation-reduction potential values (i.e., Eh values) were observed in treated cells, while positive values were observed in control cells. This indicates anaerobic conditions and high microbial activity in the cells that received amendments. After 3 winter months (November, December and January), the highest rate of perchlorate removal was observed at shallow depths. After 10 months, greater than 95% perchlorate removal was observed in shallow, medium and bottom layers of the wettest cells (cells # 4 and 6). (See Table 6 and Figures 10 and 11). The complete removal of perchlorate in the relatively less saturated plots occurred mostly at shallow depths (1- 2ft). A statistical analysis of the pilot study using SAS System 8.2 confirmed the following order of effectiveness:

Horse biosolids > Ethanol > Chicken biosolids > Control.

The removal of perchlorate from the silty clay LHAAP soils and sediments was influenced by the following two factors:

1. The length of time over which the cells remained saturated within the treatment depth of 0-0.91 m (0 – 3 ft).
2. The form in which the carbon source was applied: solid vs. liquid.

It was observed that while ponded water in treated cells had no detectable concentrations of perchlorate, the ponded water in the control cell showed the presence of perchlorate. This suggested that optimum conditions for biodegradation of perchlorate were not created in the control cell. Based on the HYDRUS-2D model and monitoring wells installed up gradient and down gradient of the treated cell, it was evident that the transport of perchlorate to groundwater was not likely. Therefore, the observed decrease in perchlorate concentration in the control cell was attributed mainly to the redistribution of perchlorate within the cell and not to biodegradation.

Some perchlorate transport is indicated in the top section of the plots (0-12”) due to the measured loss of perchlorate in the control (Figure 11). However, biodegradation of perchlorate is indicated due to the complete exhaustion of perchlorate in the soil treated with ethanol and chicken manure at depths of 24 and 36 inches, relative to a constant perchlorate concentration observed in the control cell at these depths. The results of this pilot study demonstrate that perchlorate-contaminated soils can be treated in a cost-effective manner by employing the techniques we have developed to deliver nutrient amendments to desired depths.

FIGURE 10. Carbon type effect on perchlorate biodegradation at different depths (0-12 in [yellow]; 12-24 in [red]; 24-36 in [blue]). Pilot scale demonstration-LHAAP in Karnack, Texas.

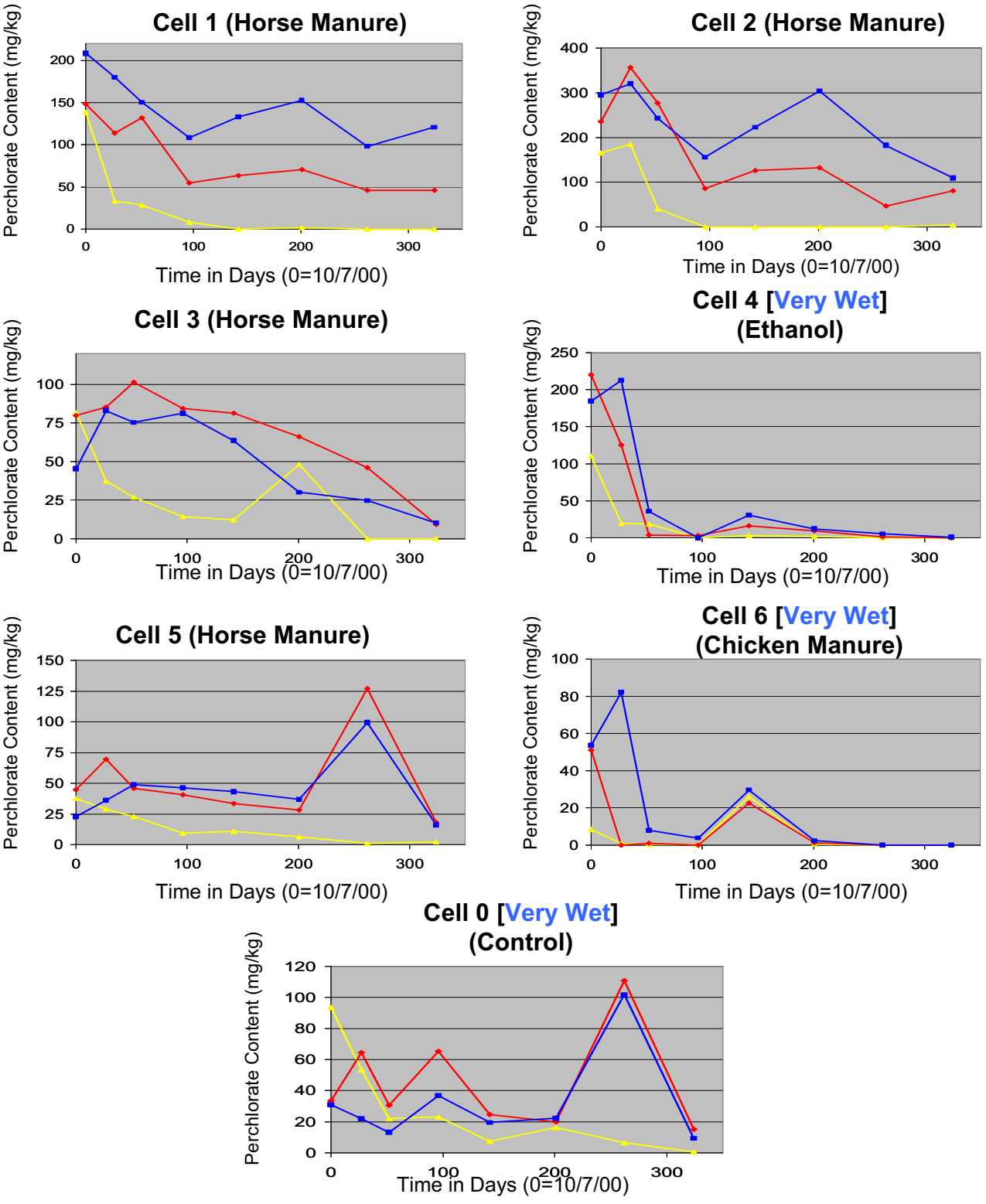
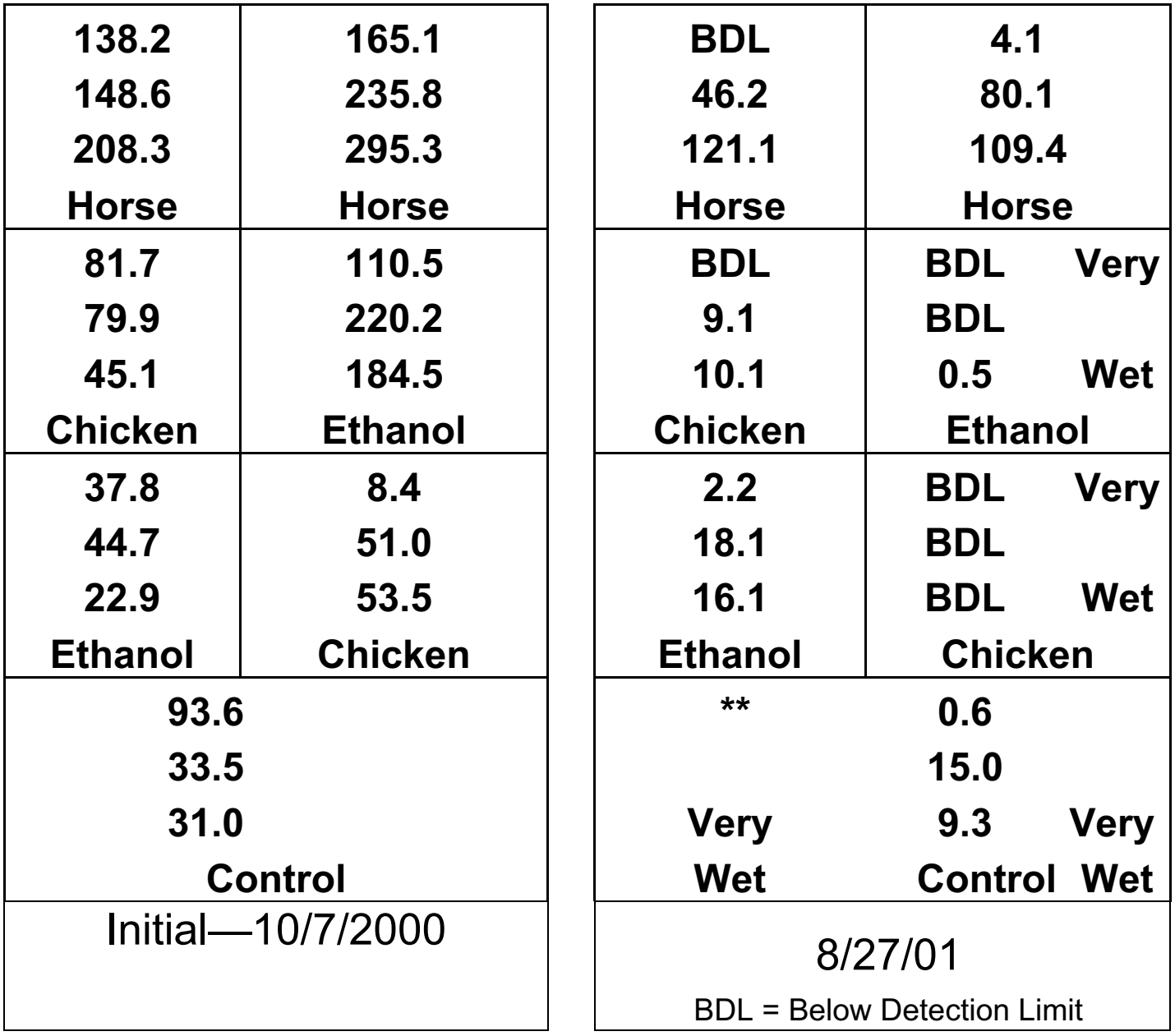
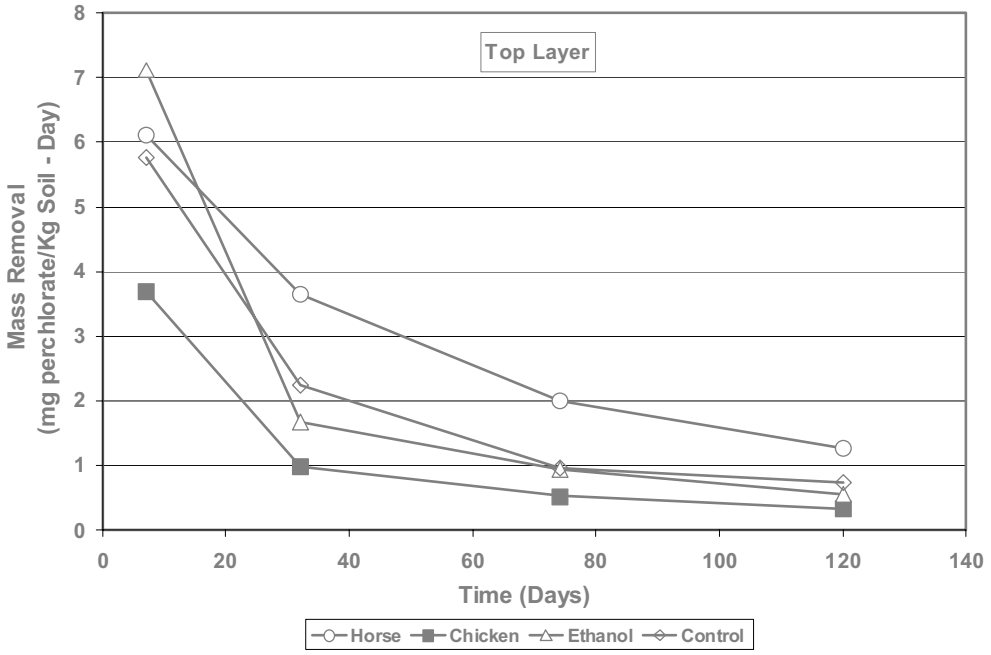


Figure 11. Baseline and final perchlorate concentrations after 10 months of treatment. Three values indicate measurements at the top, middle and bottom layers in depth.



** At the termination of the study a more even distribution of perchlorate was observed in the control but not in the treated cells.

Figure 12 [A, and B] . Mass removal from different layers within the pilot test plots over the test period of 120-days.



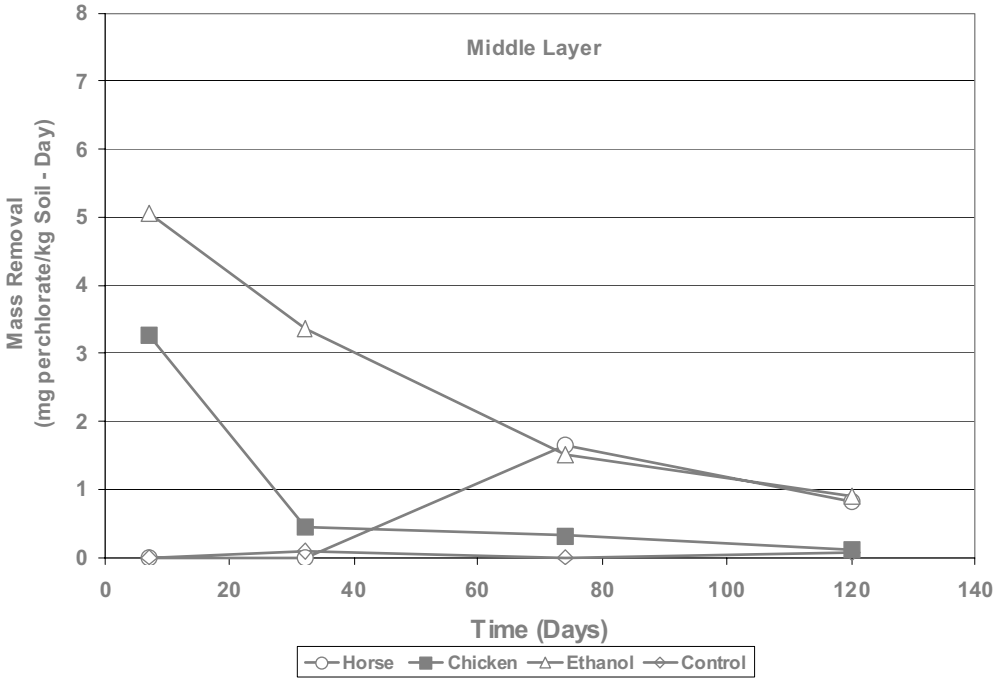
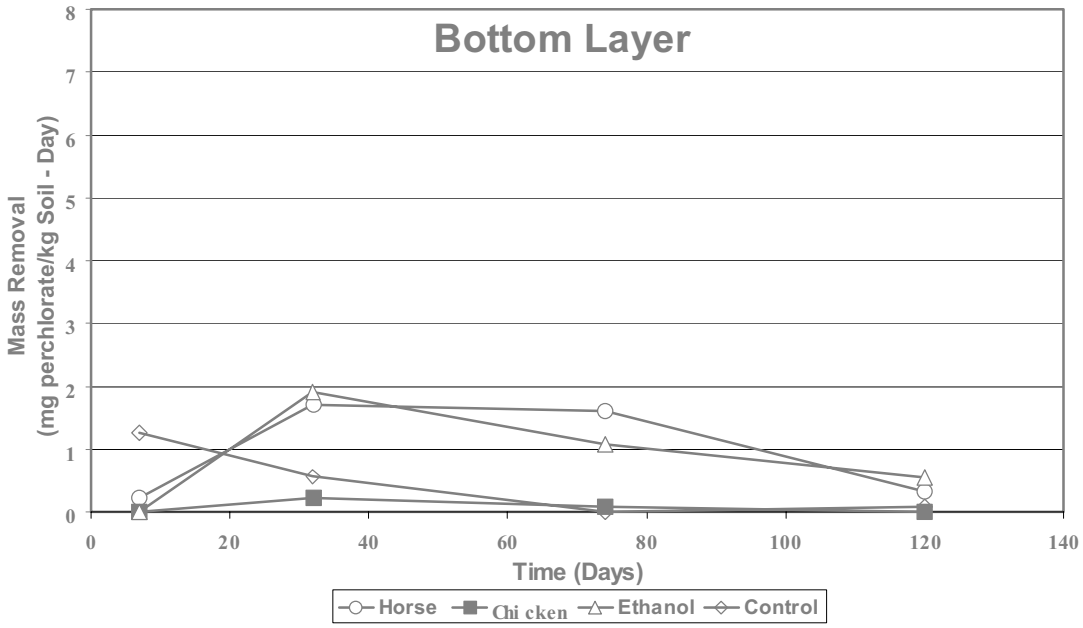


Figure 12 [C] . Mass removal from different layers within the pilot test plots over the test period of 120-days.



Figures 12 [A-C] indicate the kinetics of reduction over the 120-day duration of monitoring. In the top and middle layers, significant reduction in concentration is seen at the start of the test period. In contrast, in the bottom layer the rate of perchlorate removal [mg/kg/day] was low initially and then increased around the 30th day. This could be a result of the time required for organic carbon to reach that layer. In the initial stages, the carbon is consumed in the upper layers. Towards the 30th day, the organic carbon utilization in the upper layers has decreased, thus allowing carbon to reach the bottom layer.

Unlike the bench scale test, where chicken manure was the most effective amendment, in field tests, horse manure followed by ethanol were the most effective. One reason for this may be that that ethanol was able to disperse more easily into the soil and transport to lower layers. The manures tested were high in particulates and this could have clogged the soil pores initially, restricting organic carbon transport and biodegradation at depth. This issue needs to be addressed before further full-scale implementation.

**** control had a the smallest and very uneven distribution of perchlorate at start of study**

Plot ID	Carbon Source	Percent (%) Perchlorate Removed from		
		Top layer	Middle layer	Bottom
1	Horse manure	100	68.9	41.9
2	Horse manure	97.5	65.9	62.9
3	Chicken manure	100	88.6	77.6
4 Very Wet	Ethanol	100	100	99.7
5	Ethanol	94.3	59.5	28.8
6 Very Wet	Chicken manure	100	100	100
Control Very Wet	None	99.4**	55.1	69.8

Table 6: Percent removal of perchlorate at different depths.

V. OTHER RELATED WORK

MODELING

HYDRUS-2D was used to model water and solute transport, and perchlorate biodegradation in the vadose zone (Simunek et al., 1999). The flow equation utilized in this model is a two-dimensional variably saturated form of the Richard's Equation.

Model parameters were estimated in the following manner. A Guelph permeameter was used to determine the in-situ saturated hydraulic conductivities of the soils beneath the pilot scale location. Soil samples were collected and transported to the University of Georgia. These soil samples were utilized to further refine the saturated hydraulic conductivities using falling head permeameter methods (Lambe, 1951). Other soil samples were used to determine the water retention curves for each of the soil horizons using Tempe cells. The relationship of pressure (ψ) versus volumetric soil moisture content (θ) and hydraulic conductivity (K_u) necessary to solve the flow and transport equations were determined from the water retention curves for each soil sample using Tempe cells (Richards, 1965). The soil samples were also used to determine size fraction, cation exchange capacity, bulk density, porosity, and percent organic carbon. Biodegradation rate constants were estimated from the batch treatability studies and K_d values for perchlorate and the carbon sources determined via batch partition studies.

VI. DETERMINATION OF PARTITION COFFECIENT OF ETHANOL WITH LHAAP SOILS.

In order to determine the partition coefficient of ethanol with the LHAAP soil, a series of column studies were conducted. The evaluated transport behavior of ethanol could be used in modeling transport before further full-scale remediation. In addition, the partition coefficient can be used to directly estimate the amount of organic carbon that would be transported to defined depths based on application rates. These data and parameters would serve as design parameters when developing full-scale remediation strategies for several hundred acres.

Figures 13 and 14 show the adsorption and desorption curves for ethanol being supplied to a column of LHAAP soil. It is evident that even at very low infiltration rates, within a period of 3 to 4 days, the outlet concentration equals the inlet concentration. This indicates that the soil has very low capacity to hold organic carbon. This proposition is supported by the partition coefficient experiment (Figure 15). The calculated value of K_d based on these data is $3.1X10^{-5}$ L/kg (0.03 mL-Carbon/kg-Soil). This value appears to be much smaller than originally anticipated. Further work to evaluate the consistency and accuracy of these measurements is required.

Figure 13. Breakthrough curve of ethanol transport through a column of LHAAP soil. Inlet concentration of ethanol was 16 mg/L.

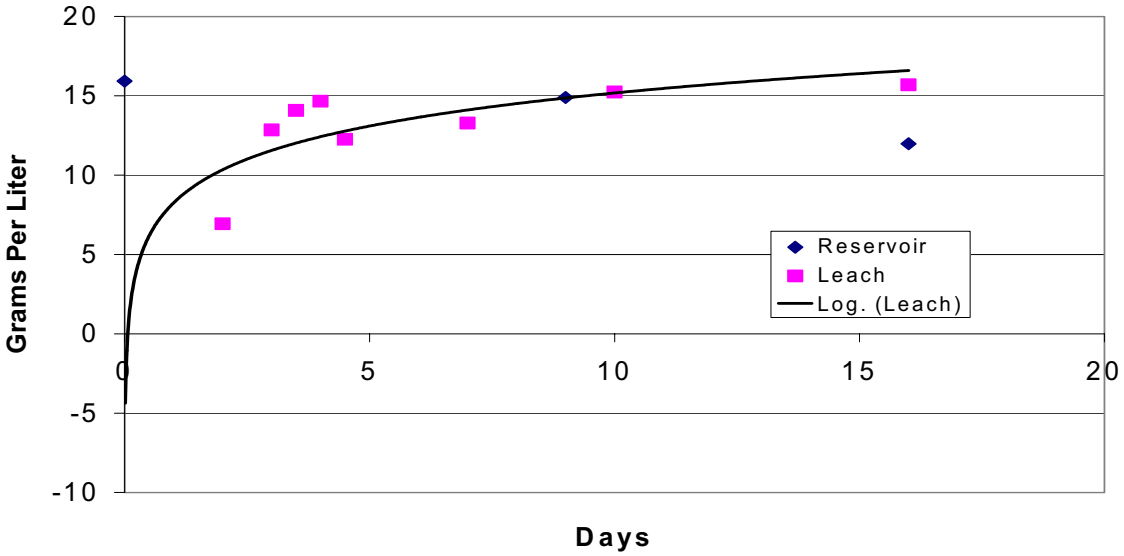


Figure 14. Breakthrough curve [Desorption] of ethanol transport through a column of LHAAP soil

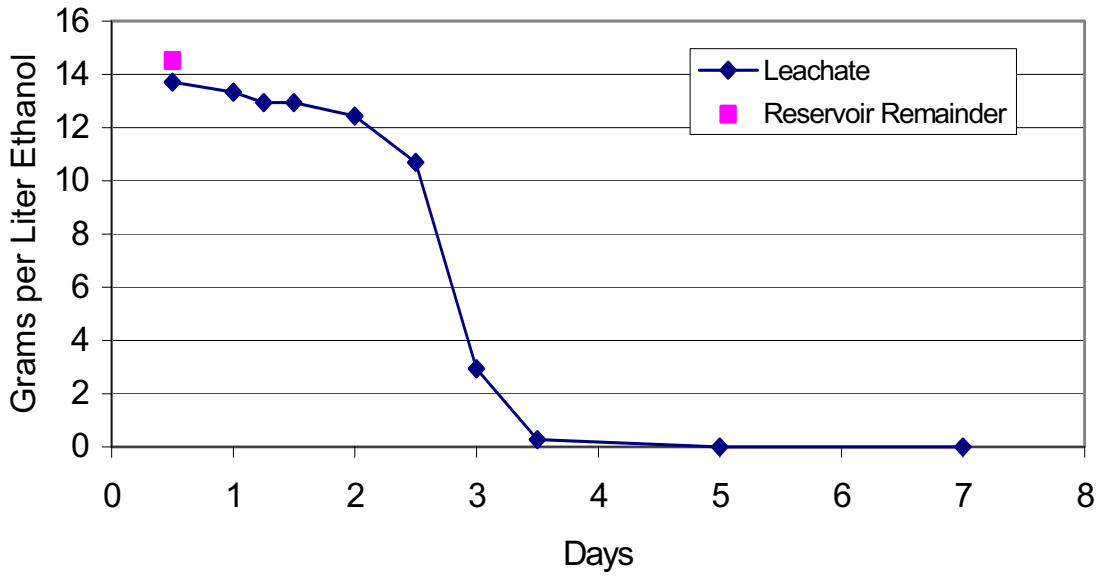
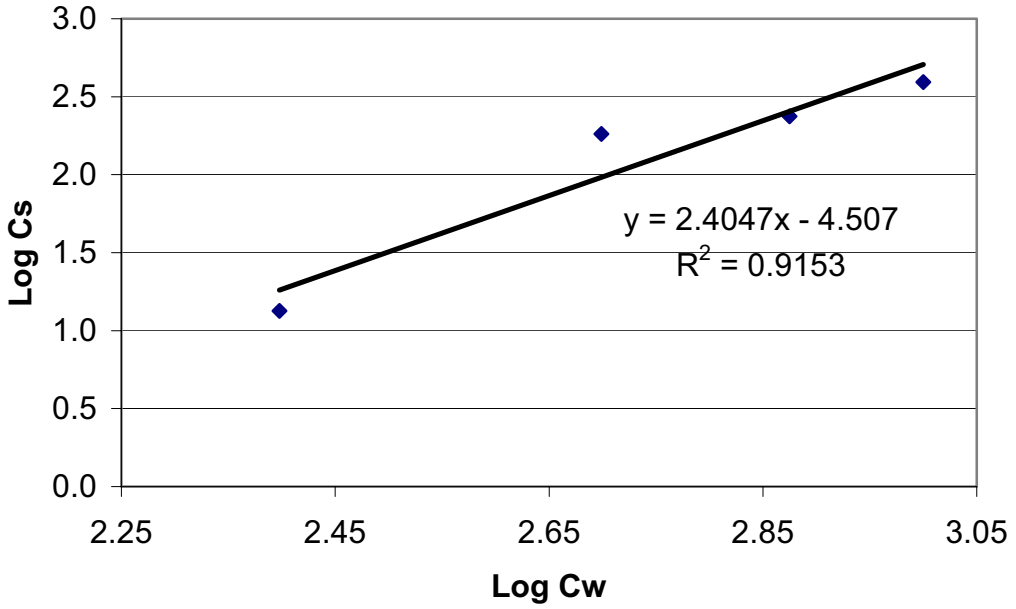


Figure 15. Freundlich isotherm for organic carbon [in ethanol] partitioning between water and LHAAP soil. EQUATION: Log C_s= Log K_d + n Log C_w is used to evaluation the partitioning coefficient K_d.



If, however, the results of these tests (Figure 15) were correct, then the strategy of supplying a continuous stream of very low concentration carbon would be required. If excess carbon is supplied, the soil's inability to absorb it will lead to lower efficiency of the system.

VII. SOIL EXTRACTION AND ANALYSIS PROCEDURES

In general, for each soil sample analyzed, six 10 g portions were weighed and placed into six extraction containers. The soil was extracted several times by homogenizing for 10 min with 100 mL of solution in a tissue homogenizer. For soils rich in organic matter (10% by weight), most of the sorbed perchlorate was desorbed using 10 mM NaOH solution. On average, three extractions were needed to completely extract the extractable perchlorate from most soils. Perchlorate is very soluble in water and does not sorb strongly to soils.

Slurry samples were sonicated for 30 minutes and allowed to cool to room temperature. The extract was separated from the aqueous-soil phase by centrifugation at 20,000 RPM for 30 minutes. The supernatant from the centrifuged samples was passed through a cartridge of prewashed activated alumina and 0.2 um Gelman Acrodisk ion membranes (Fisher Scientific, Fairlawn, NJ). These original extracts were diluted as needed before analysis by IC.

The extraction of sample and control soil samples was necessary to further verify the QA/QC of the method. Control soils would not have been exposed to perchlorate at any stage of the process. The method was validated earlier by extraction of sample and control soils dosed with $^{36}ClO_4^{1-}$ used in controlled greenhouse tests. This information was used for mass balance determination and in previous greenhouse tests, we have achieved recoveries of >92%.

VIII. PERCHLORATE MEASUREMENT PROCEDURES

Perchlorate concentration measurements in this project were conducted on water extracts using a Dionex 500 Ion Chromatograph with Conductivity Detector [IONPAC® AG11 guard column (4 x 50 mm) and IONPAC® AS 11 analytical column (4 x 250 mm)] IONPAC® AS 16 guard column (4 x 50 mm) and IONPAC® AS 16 analytical column (4 x 250 mm)

The IC is equipped with a Dionex AI-450 Chromatography Automation System and the Advanced Computer Interface Module (ACI). It has an autosampler with a holding capacity of sixty 5-mL vials. Sample injection volume of 25 µL was used for high perchlorate concentrations (ppm) or 500 uL for low concentrations (ppb). Both an IONPAC® AG16 guard column (4 x 50 mm) and IONPAC® AS 16 analytical column (4 x 250 mm) was used.

The analytical conditions developed by Dionex Corporation for analysis of low concentrations of perchlorate in drinking water and ground water by Ion Chromatography was followed. Flow rate of eluent was 1 mL/min. 50 mM NaOH solution was used for the perchlorate ion measurement. The working perchlorate concentration range will be 80-1000 ppb and the conductivity was maintained at less than 0.3 µS. The detection limit for perchlorate for the above method was 2 µg/L. The run time for this method was 15 minutes. Deionized water (resistance of 18.0 - 18.2 MΩ-CM) was used as a system blank sample to establish the baseline and to confirm the lack of

contamination in the system. Low and/or high concentration calibration curves were daily to ensure accurate quantification of perchlorate.

IX. CONCLUSIONS

Several stages of bench-scale experiments were conducted to evaluate the best organic amendment for *in-situ* soil bioremediation of perchlorate. Based on a series of column tests evaluating the transport behavior of ethanol in LHAAP soil, it appears that the soil has very low ability to adsorb carbon. This suggests that organic carbon (electron sources) can be easily transported to greater depths.

Following the initial bench scale treatability studies, a field scale test of remediation was conducted at the LHAAP site. Results show that remediation occurs with varying degrees at different depth layers. Maximum rates of perchlorate removal at the top layer during the start of the test are in the range of 6-7 mg/kg-soil/day (Figure 12A).

Initial concentrations in the test site were 8.4 to 165.1 mg/kg at the surface and 31.0 to 295.3 mg/kg at the bottom layer. After a period of 120 days, concentrations reduced to 0.0 to 0.7 mg/kg at the surface and 0 to 223.4 mg/kg at the bottom layer.

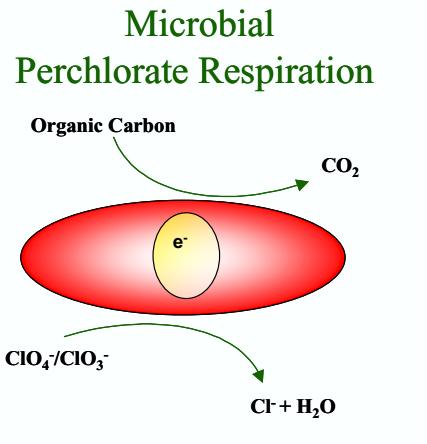
Although laboratory experiments indicated that poultry litter was a preferable amendment and had higher capacity to remediate perchlorate, the pilot test confirmed that horse manure (substitute of cow manure) and ethanol were superior amendments for in-situ bioremediation of perchlorate in LHAAP site soils.

The results of this pilot study demonstrate that perchlorate-contaminated soils can be treated in-situ by applying the techniques we have developed to deliver nutrient amendments to desired depths. We also demonstrated that the in-situ bioremediation of perchlorate-contaminated clay-rich soils could be achieved in winter, as well as summer months.

Perchlorate Treatment Technology Fact Sheet

In Situ Anaerobic Bioremediation

What is In Situ Anaerobic Bioremediation?



In situ (*i.e.*, in place) bioremediation is an innovative remedial technology that eliminates the need for aboveground treatment by using biological processes to destroy or transform contaminants in groundwater or soil while they are underground. Anaerobic bioremediation requires an absence of oxygen.

Studies have shown that perchlorate can be successfully biodegraded to the chloride ion but only anaerobically. The *in situ* anaerobic bioremediation of perchlorate is a promising technology in which naturally occurring microorganisms are used to biodegrade or consume perchlorate as a food source. For *in situ* bioremediation to occur, an electron donor (*i.e.*, carbon source) such as acetate, lactate, or molasses is added to perchlorate-contaminated groundwater or soil. The carbon source stimulates the microorganisms to degrade the contaminant *in situ*. However, *in situ* bioremediation requires careful consideration of environmental conditions, hydraulic flow, and residence time of the contaminated water in the underground reactive zone. Because perchlorate reduction has been shown to occur anaerobically, initial research into the use of *in situ* bioremediation as a means of treating perchlorate-contaminated groundwater has focused on developing and optimizing anaerobic bioremediation.

What Studies Have Investigated In Situ Bioremediation of Perchlorate?

The Strategic Environmental Research and Development Program (SERDP) is the DOD's corporate environmental R&D program, planned and executed in full partnership with the DOE and the US EPA. SERDP focuses on cleanup, compliance, conservation, pollution prevention, and Unexploded Ordnance (UXO) technologies.

In recent years, SERDP has directed significant efforts towards developing cost-effective *in situ* bioremediation technologies for perchlorate. This included funding three projects to investigate the use of *in situ* anaerobic bioremediation for treating perchlorate-impacted groundwater.

Under SERDP, Southern Illinois University is developing a library of microorganisms capable of degrading perchlorate. The effort is also investigate the following questions:

- Are perchlorate-reducing bacteria widespread in the environment?
- Do all perchlorate-reducing bacteria have a chlorite dismutase enzyme?
- Can indigenous microbial perchlorate reduction be stimulated in contaminated environments?
- Can the stimulated perchlorate-reducing bacteria population remove perchlorate concentrations to low levels?
- Will the rate of microbial perchlorate reduction be affected by environmental conditions?
- Will the stimulated perchlorate-reducing population also enhance the biodegradation of co-contaminating organics?

Project Facts

SERDP Web Site: http://www.serdp.gov

Research Description: Identify microorganisms responsible for perchlorate degradation; determine factors that influence perchlorate microbial degradation; and perform small pilot-scale test of *in situ* anaerobic bioremediation of perchlorate

Contaminated Media: Groundwater

Treatment Technology: *In situ* anaerobic bioremediation

Objective: Perform basic research to understand the factors influencing *in situ* anaerobic bioremediation of perchlorate

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Perchlorate Treatment Technology Fact Sheet
In Situ Anaerobic Bioremediation

Two private sector companies are also conducting SERDP-funded research and testing of *in situ* anaerobic bioremediation of perchlorate. Results indicate that the technology has great promise for use in treating perchlorate-contaminated groundwater. These studies have identified the critical factors that influence the effectiveness of the technology. For example, more than 30 different strains of perchlorate-reducing bacteria have been isolated from diverse environments. These bacteria appear to be widespread. The perchlorate can typically be degraded to chloride and water by the microorganisms in less than 30 days in laboratory experiments. The presence of oxygen, nitrate, and low pH are inhibitory of perchlorate reduction by these bacteria; and most perchlorate-respiring microorganisms are capable of living under varying environmental conditions.

DOD's Environmental Security Technology Certification Program (ESTCP) is also funding three projects to evaluate perchlorate treatment technologies. The goal of ESTCP is to demonstrate and validate promising, innovative technologies that target DOD's most urgent environmental needs. The three ESTC projects evaluating in situ anaerobic bioremediation of perchlorate begin in 2002. These and other current research efforts are helping to advance the technology and reduce the potential costs associated with current in situ anaerobic bioremediation of perchlorate.

Project Facts

ESTCP Web Site: http://www.estcp.org/

Research Description: The three sponsored projects will demonstrate different techniques for addition and distribution of carbon sources in the pilot scale in situ anaerobic remediation of perchlorate

Contaminated Media: Groundwater

Treatment Technology: In situ anaerobic bioremediation

Objective: Demonstrate and validate the use of in situ anaerobic bioremediation for the treatment of perchlorate

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Cost Effectiveness

Because the application of *in situ* anaerobic bioremediation technologies to perchlorate-contaminated groundwater is currently being validated, defensible cost and performance data are not yet available. Completion of the field efforts should provide valuable insight into the cost and performance of the technologies.

Advantages

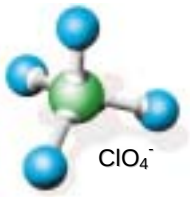
- Treats groundwater without pumping to the surface; should result in significant cost savings over pump-and-treat systems
- Biodegrades perchlorate relatively quickly; works even at low concentrations of perchlorate
- There is an apparent abundance of naturally occurring perchlorate-reducing microorganisms in environment
- Carbon sources demonstrated to date are relatively inexpensive
- May treat other soil or groundwater contaminants simultaneously with perchlorate
- Can be used to treat soil hot spots, which would prevent subsequent contamination of groundwater
- Requires minimal aboveground structures, which is aesthetically advantageous
- Land above ground is usable during treatment period

Disadvantages

- Drilling is required to deliver carbon source; targeted groundwater must be within reasonable depth limits for cost-effectiveness
- Less certain, non-uniform treatment results from variability in aquifer, climate, weather, soil characteristics
- Requires careful control of site-specific environmental characteristics (e.g. ,oxygen content, pH) to maintain optimal treatment conditions
- Free movement of microorganisms, electron donors, or treatment by-products in groundwater may impact downstream users of groundwater, requiring longer treatment time periods. Downstream monitoring wells, and capture and reinjection of treated water may be required

Perchlorate Treatment Technology Fact Sheet

Soil Biotreatment



What Is Soil Biotreatment Technology?

Soil biotreatment technology uses bacteria to degrade soil contaminants. Treatment alternatives, can be either *ex situ* (*i.e.*, above ground) or *in situ* (*i.e.*, in place, in ground), and include biotreatment cells, soil piles, and prepared treatment beds. Soil biotreatment is typically based on the principles of soil composting (controlled decomposition of matter by bacteria and fungi into a humus-like product). In *ex-situ* processes, contaminated soils are excavated, mixed with additional soil and/or bacteria to enhance the rate of contaminant degradation, and placed in aboveground enclosures or treatment cells. *In-situ* processes use a carbon source such as chicken, horse, or cow manure. *In-situ* technologies can be active or passive depending upon whether the carbon source is applied directly to the undisturbed soil surface (*i.e.*, passive) or physically mixed into the soil surface layer (*i.e.*, active). The effectiveness of both alternatives is dependent upon careful monitoring and control of environmental factors such as moisture, temperature, oxygen, and pH, and the availability of a food source for the bacteria to consume.

Ex Situ Perchlorate Soil Biotreatment

Where has Biotreatment Been Used to Treat Perchlorate-contaminated Soils?

The DOD is conducting field studies using *in-situ* and *ex-situ* soil biotreatment technologies to treat soils at the Naval Weapons Industrial Reserve Plant (NWIRP) facility in McGregor, Texas, and at the Longhorn Army Ammunition Plant (LHAAP) in Karnack, Texas. Private industry is also demonstrating *in-situ* soil biotreatment technologies in field tests at a site in California.

Perchlorate-Contaminated Soil Biotreatment, NWIRP McGregor

NWIRP McGregor soils are contaminated with perchlorate from past industrial practices associated with manufacturing solid-fuel rocket motor propulsion systems. These contaminated soils were an ongoing contributing source for groundwater contamination with perchlorate and thus needed to be addressed as part of overall cleanup activities at McGregor. As part of its aggressive perchlorate initiative, the US Navy generated a conceptual design and implemented a soil biotreatment study at McGregor. The study allowed evaluating the overall experimental approach and produced data on the optimized mixture of nutrients and carbon sources to use as well as information on the microbe populations present. Study findings indicated that perchlorate concentrations were reduced to below the US EPA-approved reporting limit in less than a year.

Following the successful study results, perchlorate-contaminated site soil was transported to an onsite, plastic-lined engineered treatment cell. Prior to placement in the cell, the soil was mixed with a carbon source, nitrogen and phosphorous fertilizer (micronutrients), soda ash (buffer), and water in quantities/ratios determined during the preliminary study. Additional water was added and the cell was covered with a plastic liner. After 6 months, soil was sampled at 6 random locations and analyzed for perchlorate. All six samples were below the target cleanup level.

Site Facts

Locations: NWIRP McGregor, Texas and Longhorn Army Ammunition Plant, Texas

Site Descriptions: Former solid rocket motor manufacturing facilities

Contaminated Media: Soil

Treatment Technology: Anaerobic landfarming

Objective: Clean up perchlorate from soils

Status: Field demonstrations

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Perchlorate Treatment Technology Fact Sheet

Soil Biotreatment

Perchlorate-Contaminated Soil Biotreatment, Longhorn Army Ammunition Plant (LHAAP)

Laboratory and field studies, supported by US Army Operations Support Command, were conducted at LHAAP to demonstrate the feasibility of *in-situ* bioremediation of perchlorate-contaminated soils. Laboratory tests identified chicken manure, cow manure, and ethanol as suitable carbon sources for the enhancement of *in-situ* bioremediation of perchlorate. After ten months, complete removal of perchlorate was observed within 1-2 feet, with varied levels of reduction in the deeper layers. At the termination of the field study, the concentration of perchlorate in the wettest cells had decreased to non-detectable levels. The results demonstrate that perchlorate-contaminated soils can be treated *in situ* by delivering nutrients and carbon sources to desired depths.

In situ bioremediation of perchlorate-contaminated soils at LHAAP

Industry Initiatives

The private sector is also investigating different methods of soil biotreatment. One of the methods is a passive, *in-situ* approach that consists of applying water-saturated cow manure to the soil surface, and allowing bacteria, moisture, and organic material from the manure layer to leach into the soil, aided by rainfall in the winter. Perchlorate-reducing bacteria present in manure and soil are then provided with the proper conditions of food, moisture, and reduced oxygen without any soil disturbance. During the first 30 days of the industry study, following initial placement of wet cow manure, biodegradation destroyed over 90% of perchlorate in the high-perchlorate areas. Other industry research has shown that alternative electron donors, such as molasses and calcium magnesium acetate, are effective at *in-situ* biodegradation of perchlorate in soils.

Cost Effectiveness

Because soil biotreatment technology is relatively new, there are not many comparable examples from which to obtain cost, performance, and long-term operation and maintenance data. However, on-site biotreatment of perchlorate-contaminated soil at NWIRP McGregor reportedly lowered remediation costs by approximately $100,000 relative to conventional excavation and offsite transportation and disposal. Data from conventional soil biotreatment technologies suggest that *ex-situ* alternatives requiring the excavation of contaminated soils will be more costly than either active or passive *in-situ* alternatives. For instance, *in-situ* biotreatment techniques applied to other contaminated soils have been estimated to cost between $25 to $50 per cubic yard; while *ex-situ* techniques (involving bed preparation and placement of soil in a prepared liner) have been estimated to cost up to $75 per cubic yard.

Advantages

- Short-term technology that can be used to treat localized hot spots
- Can be used to treat source contribution zones
- Treatment costs may be less than conventional dig-haul-treat approaches
- Passive treatment is relatively simple and inexpensive because there is no required soil mixing

Disadvantages

- *Ex-situ* treatment of contaminated soils may require significant excavation and manipulation
- Current research suggests that biological processes are most effective when the contaminant is within 18 inches of the surface
- Static, non-mechanical treatment process may result in less uniform treatment than processes that involve periodic mixing
- Potential for contamination downstream (*e.g.*, *Escherichia coli* from manure or nitrates from nutrients)
- Site specific climatic and hydrogeochemical conditions impact effectiveness.

Prepared for:

The Boeing Company
Rocketdyne Propulsion & Power

WORK PLAN FOR A LABORATORY TREATABILITY STUDY TO DEMONSTRATE PERCHLORATE BIODEGRADATION IN SOILS FROM THE SANTA SUSANA FIELD LABORATORY, VENTURA COUNTY CALIFORNIA

Prepared by:

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GeoSyntec Project Number TR0154.02
July 2003

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1.0 INTRODUCTION

GeoSyntec Consultants Incorporated (GeoSyntec) has been retained by The Boeing Company (Boeing) to conduct a laboratory biotreatability study to demonstrate the ability to biodegrade perchlorate in soils from the Happy Valley and Building 359 Areas of Concern at the Santa Susanna Field Laboratory (SSFL) in Ventura County, California (the Site). The goal of the study is to confirm that bacteria that are naturally present in soils from SSFL can effectively biodegrade the low levels of perchlorate in soils from the Site, thereby providing support for the deployment of *ex situ* soil composting and/or *in situ* bioremediation to treat perchlorate-impacted soils at the Site.

This Work Plan is divided into six sections. Section 2 provides background information on perchlorate impacts to soil in the study area, and summarizes key results from previous laboratory and field applications of bioremediation to treat perchlorate-impacted soil. Section 3 presents the study objectives. Section 4 presents the study approach and methods. Section 5 provides a project schedule. Work Plan references are provided in Section 6.

2.0 BACKGROUND

Near-surface perchlorate-impacted soils at the Site consist of disturbed soils at the perchlorate usage areas (source sites), and soils and sediments within the Happy Valley drainage that have been affected by perchlorate transported from the source sites through site drainage. The levels of perchlorate are generally lower than have been considered for soil remediation at most other sites, with levels generally less than 100 µg/kg. Past soil bioremediation applications have typically focused on the remediation of high concentration (i.e., 10 to 1000 mg/kg) perchlorate source sites, with a remedial objective of reducing perchlorate concentrations below the residential preliminary remedial goal (PRG) of 7.8 mg/kg. Few bench-scale or field studies have evaluated the ability to bioremediate low concentrations of perchlorate in soil, and studies have generally not been conducted to evaluate the lowest quantifiable concentrations that can be achieved by the soil bioremediation technology. However, multiple in situ bioremediation demonstrations in groundwater have consistently demonstrated effective biodegradation of low starting concentrations of perchlorate (e.g., 100 ug/L) to less than the practical quantitation limit (PQL) of 4 µg/L, and therefore, there is little reason to believe that similar results cannot be achieved with soil bioremediation technologies.

Two biological remediation methods have been proposed previously (MWH, June 2003) to treat perchlorate-impacted soils at the Site. The first method involves excavation of the impacted soils and removal to a separate location for anaerobic composting by the addition of carbon sources to promote bacterial growth and perchlorate-reduction within the compost pile. Once treated, the soils can be returned to the excavation or spread in place. The second method involves in situ treatment of perchlorate-impacted soils by mixing the soils with a suitable carbon source to promote bacterial growth and perchlorate-reduction. Both approaches require the addition of sufficient water to allow the development of appropriate redox conditions within the materials, but water addition must be managed properly to avoid leaching perchlorate from the soils to underlying or surrounding areas.

2.1 Key Results of Previous Soil Bioremediation Field Demonstrations

Previous studies at a rocket manufacturing site in Northern California have demonstrated that perchlorate can be effectively biodegraded in surface soils via two separate approaches: ex-situ composting (GeoSyntec, 2000); and by surface application of composted cow manure combined with limited mechanical mixing of calcium magnesium acetate (CMA) in localized hotspots containing perchlorate in the 1000's of mg/kg (Borch, 2001). The latter study demonstrated that biological remediation methods could be used to destroy perchlorate in surface soils with 10's to 100's of mg/kg of perchlorate at minimal cost and with little soil disturbance by simply applying a layer of wet composted manure to the impacted soil surface, and allowing sufficient time for the bacterial reduction of perchlorate to occur.

More recently, Nzengung et al. (2002) applied a similar technique at both bench and pilot scales to remediate perchlorate-impacted soils at the Longhorn Army Ammunition Plant (AAP) in Texas using ethanol and a variety of manure types (chicken, cow, and horse) as electron donors. In this study, starting perchlorate concentrations were reduced from 400 mg/kg to less than 0.7 mg/kg in the surface layer within the 180-day study period.

The conditions necessary for bacterial perchlorate reduction in soils are relatively straightforward: ample dissolved organic material, and moist soil conditions to limit oxygen diffusion and aid in the maintenance of reducing conditions. Studies have clearly shown that perchlorate-reducing bacteria are universally distributed in soils (ESTCP, 2002). While manure has historically been used in field applications of soil bioremediation at several rocket manufacturing sites in California, other more "socially-acceptable" electron donor alternatives to manure may be able to achieve these conditions. As an example, the road de-icing salt calcium magnesium acetate (CMA), has been successfully used as a carbon source instead of manure to successfully treat perchlorate-impacted soils at a site in Arkansas. In this project, approximately 200 lbs. of CMA were substituted for 50+ cubic yards of manure with considerable savings in cost, time, and pile construction efforts. Nzengung successfully used ethanol as well as manure in the pilot tests at Longhorn AAP. In groundwater bioremediation studies GeoSyntec has successfully used ethanol, sodium acetate, calcium magnesium acetate, citric acid, sodium lactate, and potassium oleate as carbon sources, indicating that

perchlorate reducing bacteria are not particularly sensitive to the actual carbon source (electron donor) used. However, the amount of acclimation that needs to occur prior to the onset of perchlorate reduction, and the speed at which perchlorate is reduced in soils, may be a site-specific function of both the carbon source and soil composition.

2.2 Electron Donor Selection for Bench-Scale Testing

The choice of a suitable electron donor (carbon source) for bioremediation of perchlorate in soil is a function of cost, ease of handling and application, and health and safety factors, as well as performance. In the bench scale test described herein, we propose to evaluate and demonstrate the efficacy of five different carbon sources that have potential for use in the ex situ and in situ bioremediation applications that have been proposed by MWH (June 2003): ethanol, food-grade citric acid, calcium magnesium acetate (CMA), potassium oleate, and methyl soyate. The advantages and limitations of using each of these electron donors is summarized below.

- **Ethanol** has been used successfully in multiple perchlorate bioremediation demonstrations for soil and groundwater media. It is available as a high purity material, consisting only of carbon, oxygen and water, and thus no additional dissolved materials that could interfere with perchlorate analysis by ion chromatography will be added to the soil. The cost of ethanol is relatively low. The main disadvantages of using ethanol relate to handling concerns due to flammability, and the potential for evaporative losses when used in soil bioremediation.

- **Citric acid** is a relatively low-cost product used in food manufacturing, and can easily and safely be applied as a solid granular material or dissolved in water. It has been used successfully to promote perchlorate biodegradation in groundwater at sites in California and Nevada. Similar to ethanol, it does not add anions that may affect analytical detection limits to the target media. As a possible disadvantage, citric acid can lower the pH of soils when applied at high concentrations. However, at the low application concentration that would be

required for SSFL soil bioremediation, the buffering capacity of the soil is likely to be sufficient to prevent any significant pH shift.

- **CMA** is a granular material that has been widely used as an environmentally benign alternative to sodium chloride as a road deicing salt. It has been successfully used as an electron donor in multiple field demonstrations of perchlorate biodegradation in soil and groundwater. However, it is relatively expensive and contains a high percentage of the cations calcium and magnesium which may cause difficulty in measuring very low levels of perchlorate in soils.

- **Potassium oleate** is a relatively low-cost, vegetable-based surfactant that is used as a component of soap. As a surfactant, it may be able to more completely wet soil agglomerates and thus be more uniformly distributed by mixing as a surfactant solution. It is easy and safe to handle, and has been used with success in a groundwater bioremediation demonstration at a perchlorate site in California. However, its addition to soils may result in elevated PQLs for perchlorate.

- **Methyl soyate**, popularly known as biodiesel, is a mixture of long-chain fatty acid methyl esters formed by a reaction between methanol and food-grade soybean oil. It is substantially less viscous than the vegetable oil from which is it derived, and is therefore substantially easier to apply and mix in soil than vegetable oils. One key advantage of methyl soyate over the other proposed carbon sources is that it is less readily available to microorganisms, thus prolonging the time over which is available to bacteria. While edible oils have been used to biodegrade perchlorate in groundwater at bench- and field-scale, methyl soyate has yet to be tested for soil bioremediation at field scale.

3.0 STUDY OBJECTIVES

The objectives of the proposed bench-scale study are to:

1. Demonstrate that perchlorate in the SSFL soils, present at low starting concentrations, can be biodegraded by the addition of water and simple carbon substances in controlled, bench-scale tests;

2. Evaluate the impact of electron donor addition and the development of perchlorate-reducing conditions within the soils on the analytical methodology (i.e., do the various electron donors affect the PQL), and evaluate the lowest perchlorate concentrations that can be achieved through soil bioremediation with the various electron donors; and

3. Generate design data for the rapid implementation of field trials of both *ex situ* soil composting and *in situ* shallow soil treatment.

The scope of work to address these objectives is presented in Section 4.

4.0 APPROACH AND METHODS

The pilot test will be divided into four tasks, which will consist of: i) collection, homogenization and characterization of a representative perchlorate-bearing soil from the SSFL site; ii) construction of bench-scale soil bioremediation units for each of the five potential carbon sources; iii) biodegradation performance monitoring; and iv) reporting. These tasks are briefly discussed below. Methods may be modified during the course of the study based on best judgement and data that comes available during the study. Departures from the proposed methodology and the reasons for such departures will be documented in the Laboratory Biotreatability Report.

4.1 Task 1 – Soil Collection, Homogenization, and Characterization

A well-homogenized and well-characterized reference site soil will be required for the bench scale tests. Approximately 25 kilograms (5 gallons) of SSFL soil with a target perchlorate concentration of 100 to 500 µg/kg will be collected and prepared by MWH personnel. The soil will be sieved to <2 millimeters, and thoroughly homogenized. Three representative splits of the reference soil will be taken and analyzed for perchlorate, nitrate, sulfate, and total organic carbon. The reference soil will then be shipped to GeoSyntec's biotreatability laboratory in Guelph, Ontario where the soil bioremediation units will be constructed and incubated. While construction, incubation and sampling of the soil bioremediation units will be done at the GeoSyntec Biotreatability Laboratory, all analyses will be conducted by a California-certified laboratory selected by MWH.

4.2 Task 2 – Construction of Soil Bioremediation Units

The bench-scale tests will be prepared by adding 225 g of reference soil to 250 ml Erlenmeyer flasks. An amount of electron donor equivalent to four times the stoichiometric requirement based on balanced redox reactions for oxygen, nitrate, and perchlorate will then be added to the flask, followed by sufficient deionized water to wet the soil to 40% by volume (approximately 70 ml). Table 1 provides an estimate of the mass of each donor that will be required, assuming that the perchlorate and nitrate

concentrations are 500 µg/kg and 5 mg/kg, respectively, that the oxygen concentration in the added water is 8.5 mg/L, and that there is 40 mL of air in the headspace with an oxygen concentration of 700 mg/L. Oxygen in the headspace accounts for approximately 95% of the total electron donor demand, and in the field the amounts of electron donor used are thus likely to be conservative as the volume to surface area ratio will be lower in the field. The quantities listed in Table 1 will be modified based on measurements of perchlorate, nitrate, and bulk density of the reference soil.

A total of 15 flasks will be prepared for each treatment The flasks will be incubated and sacrificed for analysis as described in the following section.

4.3 Task 3 – Performance Monitoring

Table 2 summarizes the anticipated performance sampling schedule. The flasks will be prepared for analysis by transferring the entire contents to a 500 ml Erlenmeyer and adding an additional 155 ml of DI water, bringing the total amount of added DI water to 225 ml. Perchlorate will be extracted by placing the 500 ml extraction flasks on a laboratory shaking table and agitating for 12 hrs under aerobic conditions. The extractant solution will then be decanted and filtered, and then shipped to a California-certified laboratory for analysis. Sufficient extract will be available so that various cleanup options for the extracts can be tested in order to achieve the lowest PQL for perchlorate, and a standard operating procedure developed. In addition to perchlorate, nitrate and sulfate will be analyzed.

The preliminary schedule (Table 2) calls for samples to be sacrificed after 3 days, 1 week, 2 weeks, 4 weeks, and 8 weeks of incubation of the soil bioremediation units. This schedule will be shortened or lengthened as necessary to appropriately monitor biodegradation performance. The active control samples will be analyzed after four weeks, and again at the end of the study.

4.4 Task 4 – Reporting

During the course of the study, MWH will provide GeoSyntec with the laboratory results as they are obtained, and GeoSyntec will in turn prepare weekly progress summaries to distribute to Boeing and MWH.

At the conclusion of the study, the data obtained from the bench test will be tabulated, reviewed and interpreted to estimate the rate and extent of perchlorate biodegradation with each carbon source, and to estimate the PQL that can be expected during field implementation of soil bioremediation. GeoSyntec will prepare a draft report containing detailed study methods, all data generated during the study, our assessment of the data, conclusions, and recommendations for full-scale application of the bioremediation approach for soils and sediments at the Site. GeoSyntec will also prepare work plans for rapid implementation of field-scale pilot tests for the ex situ and in situ soil bioremediation approaches.

5.0 SCHEDULE

Assuming approval of this Work Plan by the agencies and receipt of the homogenized soil by the GeoSyntec biotreatability laboratory by 8 August 2003, then we anticipate that performance monitoring will be completed no later than 3 October 2003, depending on microbial acclimation and biodegradation rates. A draft report will be prepared within 2 weeks of receipt of all laboratory data. In the event that biodegradation is more rapid and the full 8 weeks of incubation is not required, or preliminary results are sufficiently encouraging, work plans for a pilot test(s) may be submitted in advance of preparing the final report for of the bench scale tests.

6.0 REFERENCES

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TABLE 1: SUMMARY OF SOIL BIOREMEDIATION TREATMENTS & CONTROLS

Soil Bioremediation Laboratory Study, Santa Susana Field Laboratory, Ventura County, California

Treatment	Soil Mass (g)	Mass Carbon Source (mg)	Volume De-ionized Water (mL)
Active Control	225	0	70
Ethanol	225	56	70
Citric Acid	225	156	70
CMA	225	152	70
Potassium Oleate	225	44	70
Methyl Soyate	225	40	70

TABLE 2: ANTICIPATED PERFORMANCE MONITORING SCHEDULE

Soil Bioremediation Laboratory Study, Santa Susana Field Laboratory, Ventura County, California

Treatment	3 days	1 week	2 weeks	4 weeks	8 weeks
Active Control	3	3	3	3	3
Ethanol	3	3	3	3	3
Citric Acid	3	3	3	3	3
CMA	3	3	3	3	3
Potassium Oleate	3	3	3	3	3
Methyl Soyate	3	3	3	3	3